Synthesis Report

Climate resilient drinking water infrastructure based on a demand- supply and gap analysis

For 39 Unions of 5 Upazilas under Khulna and Satkhira District

June 22, 2017

Submitted to:

UNDP by WaterAid Bangladesh

Abbreviation

ACS	:	Appreciative Consulting Services
BDT	:	Bangladeshi Taka
BOT	:	Build – Operate – Transfer
BWDB	:	Bangladesh Water Development Board
CBO	:	Community Based Organisation
CCTF	:	Climate Change Trust Fund
DPHE	:	Department of Public Health Engineering
GIS	:	Geographic Information System
GOB	:	Government of Bangladesh
HH	:	Household
ICCAD	:	International Conference on Computer Aided Design
ITN-BUET	:	International Training Network – Bangladesh University of Engineering and Technology
JMP	:	Joint Monitoring Programme
KM	:	Kilometer
LGSP	:	Local Government Support Project
LPCD	:	Liter Per Capita Per Day
LPD	:	Liter Per Day
MAR	:	Managed Aquifer Recharge
MIS	:	Management Information System
MoEF	:	Ministry of Environment and Forest
NAPA	:	National Adaptation Programme of Action
O&M	:	Operation and Maintenance
PPP	:	Public Private Partnership
PPT	:	Parts Per Thousand
PRA	:	Participatory Rural/Rapid Appraisal
PSF	:	Pond Sand Filter
PWS	:	Piped Water System
RO	:	Reverse Osmosis
RWH	:	Rain Water Harvesting
RWHS	:	Rain Water Harvesting System
SMC	:	School Management Committee
Sq.km	:	Square Kilometer
UNDP	:	United Nations Development Programme
UNICEF	:	United Nations Children's Emergency Fund
UP	:	Union Parishad
WAB	:	WaterAid Bangladesh
WSP	:	Water Safety Plan
WSP-WB	:	Water and Sanitation Program – The World Bank

Contents

1. Introduction

1.1 Project Background and Objectives

This report comprises a comprehensive drinking water supply and demand analysis of the communities (hereinafter called as 'the study') of 39 Unions[1] under 5 selected Upazilas[2] of Khulna and Satkhira districts of Bangladesh, and proposes climate-resilient technology solutions to provide a sustainable water supply for the communities. The operation and access to these technological solutions will be accompanied with proven interventions to improve or create institutional arrangements/mechanisms, which will, particularly, facilitate women empowerment. This report will provide relevant information for the Green Climate Fund (GCF) project proposal, entitled "Enhancing Women and Girls Adaptive Capacity to Climate Change in Bangladesh". The project was proposed by the Government of Bangladesh (GoB) and the development of the proposal is supported by United Nations Development Programme (UNDP). The Ministry of Women and Children's Affairs (MoWCA) of GoB will be the key implementing partner for the project. As part of the process, WaterAid Bangladesh is playing an anchoring role to support GOB-UNDP by leveraging its long and demonstrated sectoral experience as well as outsourcing consultancy services.

1.2 Methodology

The study was mainly based on qualitative research methods, i.e. a Participatory Rapid Appraisal (PRA) process for identification and mapping of functional[3] and potential[4] drinking water sources (as per agreed definitions – see footnotes 3 & 4) in the communities at household, community, and institutional levels. A comprehensive literature review of secondary sources complements primary data and facilitates the identification of the most feasible interventions.

The PRA process involves two stages of participatory community consultation – firstly, at Ward level (i.e. Ward PRA on water source mapping) with knowledgeable community members (both men and women) represented by various social groups (comprising 8-10 participants in each session), e.g. elected Ward members, teachers, housewives, religious leaders and social workers[5]. The participants of Ward level PRA session were selected and invited by the concerned Ward member[6]. In the PRA session, social maps were developed and the existing functional and potential water sources were identified in the maps. Further, the proposed need of water points was assessed by the participants. A checklist was used in the PRA session to collect demographic, technology options (being used for drinking water purpose), water sources, disaster, climate change, and gender related information from each Union under the study, and then information were compiled per upazila and then per district. Tables 1.2.1 to 1.2.6 presented below shows the total and upazila wise gender-disaggregated participant numbers of community and Union Parishad (UP) representatives attended the PRA process/sessions undertaken at Ward and Union levels.

At Union level, 9 Ward maps were compiled by using Union maps where all ward level information of

[1] Out of a total 49 Unions under five specific upazilas selected by GOB/UNDP
[2] Upazilas include 3 e.g. Paikgacha, Koyra and Dacop from Khulna district, and 2 e.g. Shyamnagar and Assasuni from Satkhira district
[3] Water sources/options that are currently being used by the local communities for drinking purposes
[4] Water sources/options that are newly installed but yet to be operational as well as options that are presently not working/functional but with little repair and maintenance those will become functional
[5] Community members and Ward members are different, while a UP Ward is a lowest tire of Bangladesh local government structure beyond Union Parishad (a Union consists of 9 Wards) and constituted by a number of communities/villages
[6] Ward Member is one of the elected representatives of the lowest tire of local government structure i.e. UP

existing (including potential) water technology options were first plotted, and therefore based on apparently identified gaps (in terms of coverage of households and pocket areas where there are no options exist) proposed technology options were cited/plotted in consultation with respective UP Chairman and Members (both male and female) including the secretary. Upazila-wise representatives in PRA sessions are given in Tables 1 to 6 below:

Table 1: Total representation of communities and local government representatives in the PRA process

Upazila	# of Union	# of UP Wards	# of PRA sessions	# of Participants by Upazila			Population
				Male	Female	Total	
1. Paikgacha	5	45	50	294	105	399	198,110
2. Koyra	7	63	70	418	157	575	344,501
3. Dacop	9	81	90	546	286	832	205,648
4. Shyamnagar	8	72	80	457	259	716	301,264
5. Assasuni	10	90	100	633	341	974	399,809
Total:	***39***	***351***	***390***	***2,348***	***1,148***	***3,496***	***1,449,332***

Male: 67.2% Female: 32.8%

Table 2: Participants attended in the PRA process at Paikgacha Upazila

Name of Union	# of Union	# of Wards	# of PRA sessions	# of Participants by Union			Population
				Male	Female	Total	
Deluti	1	9	10	57	19	76	24,385
Lata	1	9	10	53	24	77	19,030
Soladana	1	9	10	65	19	84	35,315
Garaikhali	1	9	10	55	22	77	44,880
Chandkhali	1	9	10	64	21	85	74,500
Total:	***5***	***45***	***50***	***294***	***105***	***399***	***198,110***

Male: 73.7% Female: 26.3%

Table 3: Participants attended in the PRA process at Koyra Upazila

Name of Union	# of Union	# of Wards	# of PRA sessions	# of Participants by Union			Population
				Male	Female	Total	
Moheswaripur	1	9	10	64	20	84	67,000
Amadi	1	9	10	63	19	82	52,422
Bagali	1	9	10	52	25	77	60,976
Moharajpur	1	9	10	55	20	75	56,490
Koyra	1	9	10	55	28	83	52,806
North Bedkashi	1	9	10	66	26	92	24,984
South Bedkashi	1	9	10	63	19	82	29,823
Total:	***7***	***63***	***70***	***418***	***157***	***575***	***344,501***

Male: 72.7% Female: 27.3%

Table 4: Participants attended in the PRA process at Dacope Upazila

Name of Union	# of Union	# of Wards	# of PRA sessions	# of Participants by Union			Population
				Male	Female	Total	
Sutarkhali	1	9	10	67	22	89	44,127
Kailashganj	1	9	10	59	36	95	19,146

Name of Union	# of Union	# of Wards	# of PRA sessions	# of Participants by Union			Population
				Male	Female	Total	
Banishanta	1	9	10	53	35	88	25,520
Laudubi	1	9	10	54	41	95	26,424
Bajua	1	9	10	61	30	91	20,240
Kamarkhola	1	9	10	68	27	95	13,905
Dacope	1	9	10	55	34	89	11,500
Pankhali	1	9	10	63	32	95	20,335
Tildanga	1	9	10	66	29	95	24,451
Total:	***9***	***81***	***90***	***546***	***286***	***832***	***205,648***

Male: 65.6% Female: 34.4%

Table 5: Participants attended in the PRA process at Shyamnagar Upazila

Name of Union	# of Union	# of Wards	# of PRA sessions	# of Participants by Union			Population
				Male	Female	Total	
Gabura	1	9	10	54	25	79	36,057
Burigoalini	1	9	10	52	40	92	45,786
Munshiganj	1	9	10	51	27	78	43,380
Ramjan Nagar	1	9	10	57	32	89	30,844
Kaikhali	1	9	10	68	28	96	32,230
Atulia	1	9	10	54	39	93	44,962
Padmapukur	1	9	10	60	32	92	29,867
Kashimari	1	9	10	61	36	97	38,138
Total:	***8***	***72***	***80***	***457***	***259***	***716***	***301,264***

Male: 63.8% Female: 36.2%

Table 6: Participants attended in the PRA process at Assasuni Upazila

Name of Union	# of Union	# of Wards	# of PRA sessions	# of Participants by Union			Population
				Male	Female	Total	
Pratapnagar	1	9	10	63	33	96	41,825
Anulia	1	9	10	62	39	101	43,000
Khajra	1	9	10	47	45	92	38,775
Sreeula	1	9	10	74	23	97	38,809
Assasuni	1	9	10	54	41	95	38,500
Bardal	1	9	10	69	33	102	45,630
Budhata	1	9	10	72	29	101	58,100
Kadakati	1	9	10	55	40	95	22,720
Kulla	1	9	10	67	29	96	38,630
Durgapur	1	9	10	70	29	99	33,820
Total:	***10***	***90***	***100***	***633***	***341***	***974***	***399,809***

Male: 65.0% Female: 35.0%

The analyses of collected data are presented in Upazila and Union profiles of the report. In recommending the climate resilient, gender sensitive, and sustainable technological options per site, professional judgments of the consultants were used, based on community preferences, and nationally acceptable appropriate technological options for saline coastal zones of the country. Nationally recognized standard and proven[7] Operation and Maintenance models[8] have been considered for cost estimation and recommendations on institutional arrangement/mechanism of each proposed water supply technology options.

This synthesis report is developed based on the compiled five Upazila reports having enriched with the desk review of secondary references as available. While, prior to this, Upazila reports were generated through compilation of relevant Union reports, and at the beginning of the process 39 Union reports were built mainly based on primary data collected through the PRA process undertaken in the communities under the selected Upazilas of two coastal district of Bangladesh. During the development of Union and Upazila reports, a separate review of relevant secondary data sources was undertaken, particularly relevant to the studied Unions and Upazilas.

[7] National Encyclopedia of Bangladesh

[8] Cited standards and models are detailed and referred to their relevant sources (including examples) in the Section 7 titled "institutional arrangement/mechanism"

2. National and Coastal Context

2.1 Geographic Location

The physical geography of Bangladesh is varied and has an area characterised by two distinctive features: a broad deltaic plain subject to frequent flooding, and a small hilly region crossed by swiftly flowing rivers. The country has an area of 147,610 square kilometres (56,990 sq mi) and extends 820 kilometres (510 mi) north to south and 600 kilometres (370 mi) east to west. Bangladesh is bordered on the west, north, and east by a 4,095 kilometres (2,545 mi) land frontier with India and, in the southeast, by a short land and water frontier (193 kilometres (120 mi)) with Burma (Myanmar). On the south is a highly irregular deltaic coastline of about 580 kilometres (360 mi), fissured by many rivers and streams flowing into the Bay of Bengal[9].

Roughly 80% of the landmass is made up of fertile alluvial lowland called the Bangladesh Plain. The plain is part of the larger Plain of Bengal, which is sometimes called the Lower Gangetic Plain. Although altitudes up to 105 metres (344 ft) above sea level occur in the northern part of the plain, most elevations are less than 10 metres (33 ft) above sea level; elevations decrease in the coastal south, where the terrain is generally at sea level. With such low elevations and numerous rivers, water and concomitant flooding—is a predominant physical feature. About 10,000 square kilometres (3,900 sq mi) of the total area of Bangladesh is covered with water, and larger areas are routinely flooded during the monsoon season. The only exceptions to Bangladesh's low elevations are the Chittagong Hills in the southeast, the Low Hills of Sylhet in the northeast, and highlands in the north and northwest. The Chittagong Hills constitute the only significant hill system in the country and, in effect, are the western fringe of the north-south mountain ranges of Burma and eastern India. The Chittagong Hills rise steeply to narrow ridge lines, generally no wider than 36 metres (118 ft), with altitudes from 600 to 900 metres (2,000 to 3,000 ft) above sea level. At 1,052 metres (3,451 ft) altitude, the highest elevation in Bangladesh is found at Mowdok Mual, in the southeastern part of the hills. Fertile valleys lie between the hill lines, which generally run north-south. West of the Chittagong Hills is a broad plain, cut by rivers draining into the Bay of Bengal that rises to a final chain of low coastal hills, mostly below 200 metres (660 ft) that attain a maximum elevation of 350 metres (1,150 ft). West of these hills is a narrow, wet coastal plain located between the cities of Chittagong in the north and Cox's Bazar in the south. About 67% of Bangladesh's nonurban land is arable. The alluvial soils in the Bangladesh Plain are generally fertile and are enriched with heavy silt deposits carried downstream during the rainy season[10].

Understanding the consequences of climate change in Bangladesh requires understanding the country's physical geography. Located on a delta, Bangladesh's physical geography is not static, and rather is always evolving as the river system continues to shift and turn, eroding land as well as accreting it. It is in part this dynamism of the country's physical geography that makes it so susceptible to climate change, since slight shocks and changes in the river delta ecosystem can cause considerable changes.

2.1.1 Bengal Delta River System

Two Himalayan rivers, the Ganges and the Brahmaputra, together with another non-Himalayan river, the meghna, forms one of the largest delta in the world known as the Ganges-Brahmaputra Delta or the

[9] Wikipedia: Bangladesh – last updated February 25, 2017
[10] Wikipedia: Bangladesh

Bengal Delta. On its northeastward migration, the Ganges built several deltas and then leaving them finally occupies its present position. The Brahmaputra had an eastward course as revealed by rennell's atlas, building the early Brahmaputra delta near Mymensingh. Now the river has a straight southward course. However, while these two rivers previously connected individually to the Bay of Bengal, at present they combine before finally emptying into the bay. These delta building activities of the rivers contributed to the formation of some 60% of the total Bangladesh coastline.[11]

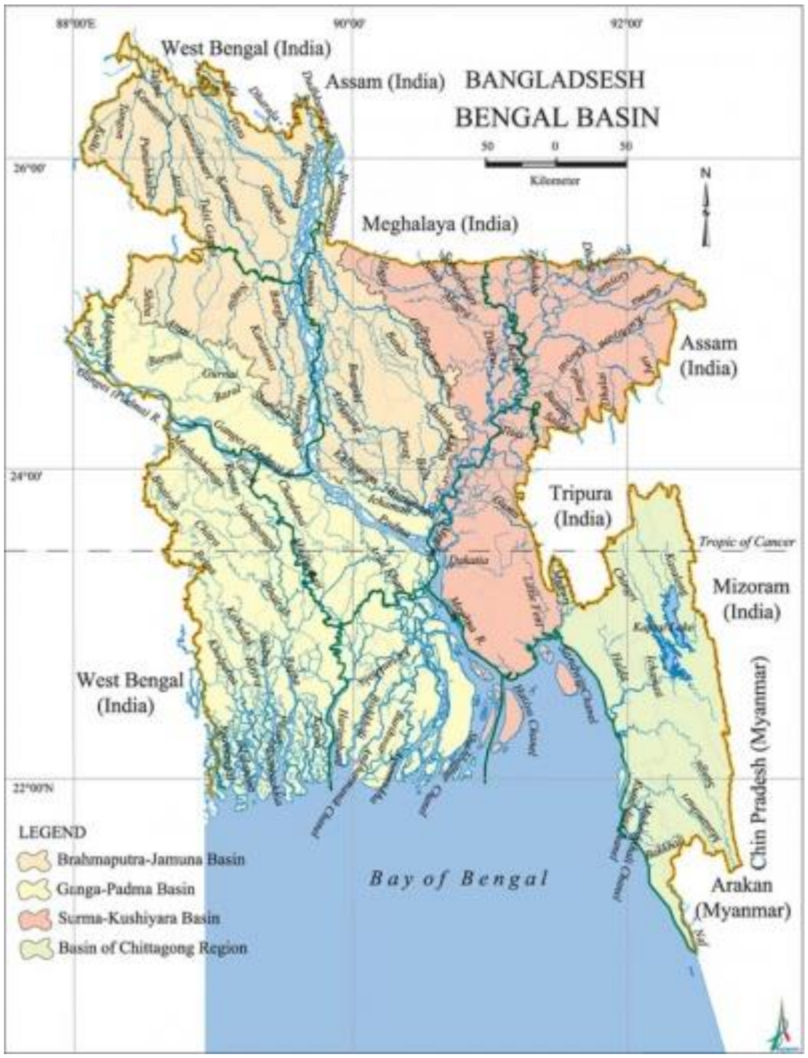

Figure 1: Bengal Delta River System (Banglapedia)

Approximately 24 thousand kilometres of major and minor rivers (Rahman et al., 1990) made up the vast surface water system of Bangladesh, among which the most significant are the Ganges, Brahmaputra and Meghna. There are 405 rivers crisscrossing the country, among which 57 are trans-boundary (BWDB, Land of Rivers, 2014). The system can be divided into four major networks: (1) Brahmaputra-Jamuna river system, (2) Ganges-Padma river system, (3) Surma-Meghna river system, and (4) Chittagong region river

[11] Banglapedia, National Encyclopedia of Bangladesh

system[12]. The rivers constitute the worlds' second largest riverine drainage basin and third largest freshwater outlet to the world's oceans, being exceeded only by the Amazon and the Congo River systems (Chowdhury and Ward, 2004).

2.1.2 Low Lying Coastal Areas

The coastal zone of Bangladesh includes 19 districts alongside the coastline of 710 km. The coastal zone extends over 47,150 sq km area and has a population of 38.52 million[13]. The coastal zone is quite different from the rest of the country and has been characterized by three feature (i) Level of tidal fluctuations, (ii) Salinity condition (both surface and ground water) and (iii) Risks of cyclone, storm surge and tidal influence.

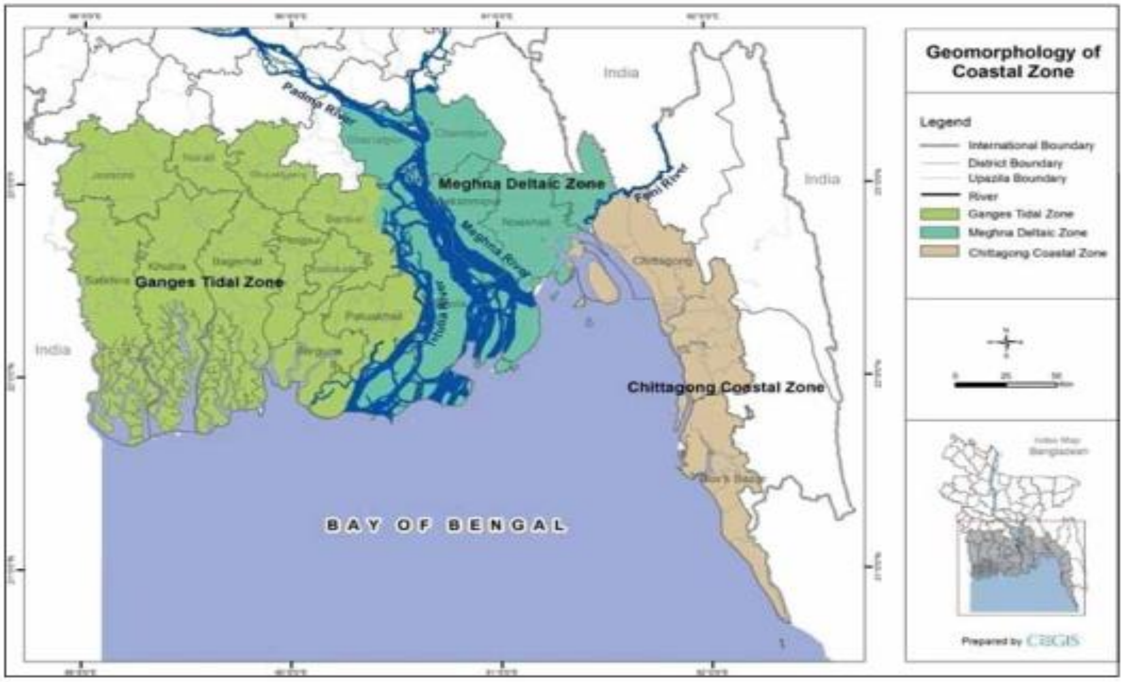

Figure 2: Delineated Coastal Zone based on Geo-morphological Characteristics (MoEF, 2016)

The 19 coastal districts have been further divided into interior (7 districts, 48 upazilas) and exposed (12 districts, 99 upazilas) zones, with regards to distance from the coast or the estuaries, under the Integrated Coastal Zone Management Project (ICZMP) of Water Resources Planning Organization (WARPO). The zone is characterized by a vast network of rivers and channels, enormous discharge of water with huge amount of sediments, many islands, the Swatch of No Ground (underwater canyon located 45 km south of the Sundarbans in Bangladesh), shallow northern Bay of Bengal, strong tidal influence and wind actions, tropical cyclones and storm surges.

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[12] Banglapedia, National Encyclopedia of Bangladesh

[13] BBS 2011

The coastal zone has been divided into three regions based on the hydro-morphological characteristics, (i) The Ganges Tidal Plain or the Western Coastal Region, (ii) The Meghna Deltaic Plain or the Central Coastal Region and (iii) The Chittagong Coastal Plain or the Eastern Coastal Region (Pramanik, 1983 cited in Islam, 2001; BUET and BIDS, 1993) (figure 2). The average elevation of the southwest coastal zone ranges from 1-2 m and in the southeast coastal zone 4-5 m.[14] The flat topography, active delta and dynamic morphology play a significant part in its vulnerability to sea level change.

Figure 3. Affected areas in coastal zone

The country is a low-lying very flat delta. Apart from the hilly regions in the northeast and southeast corners of the country, most of Bangladesh is less than 10 m above sea level. The average elevation of the southwest coastal zone ranges from 1-2 m and in the southeast coastal zone 4-5 m. The flat topography, active delta and dynamic morphology play a significant part in its vulnerability to sea level change.

The coastal zone extends from the Bangladesh-India border in the west to the Tetulia River in the east. It is mainly covered by the Sundarbans mangrove forest, greater Khulna and part of Patuakhali district. The zone is relatively stable because of the mangrove forest which acts as a natural barrier against cyclones, storm surges and soil erosion. Swamps, tidal flood plain and natural levees are found with numerous tidal creeks. This zone is a semi active delta mostly composed of silty loams or alluvium washed down from the Himalayas (Islam, 2001).

The coastal areas is a tidal river zone with narrow levees adjoining the numerous tidal rivers and creeks which are criss-crossed along the region. The western part of the South West region remains more saline than the eastern part. This is because of the Gorai River, distributary from the Ganges, is the only significant upstream fresh water source in the western part of the region, and suffers a serious decline in dry season freshwater inflows under post Farakkha condition. The eastern part of South West region remains less saline as it receives freshwater flow from the Padma and lower Meghna River through Arial Khan, Bishkhali and Buriswar River (IWM, 2014). As a result, salinity levels in the region decrease from west to east as well as from south (the Bay of Bengal) to north. It has been reported that Saline river water accumulates more than 150 km inland in the west during dry season but only 50 km in east.

2.2 Hydrological Systems and Climate

2.2.1 Temperature

[14] Assesment of Sea Level Rise on Bangladesh Coast through Trend Analysis, July 2016

During the past 32-year period (1977-2008) an increasing trend has been observed in the mean annual temperature, mean maximum temperature and mean minimum temperature by 0.016˚C/year, 0.02˚C/year and 0.012˚C/year respectively (Mukherjee et al., 2010). Statistically significant correlation (both parametric and non-parametric) in terms of rise in mean temperature is found valid in 8 out of 13 observatories in the coastal zone. Significant rise in minimum temperature and mean maximum temperature is also observed in 8 out of 13 observatories (Mukherjee et al. 2010).

Long term mean of country-average monthly minimum temperature ranges from 12.5°C in January, in winter to above 25°C in summer. The maximum temperature ranges from 25°C in winter,with a peak in summer, in April (33.5°C). A secondary peak is observed in September (31.6°C).[15]

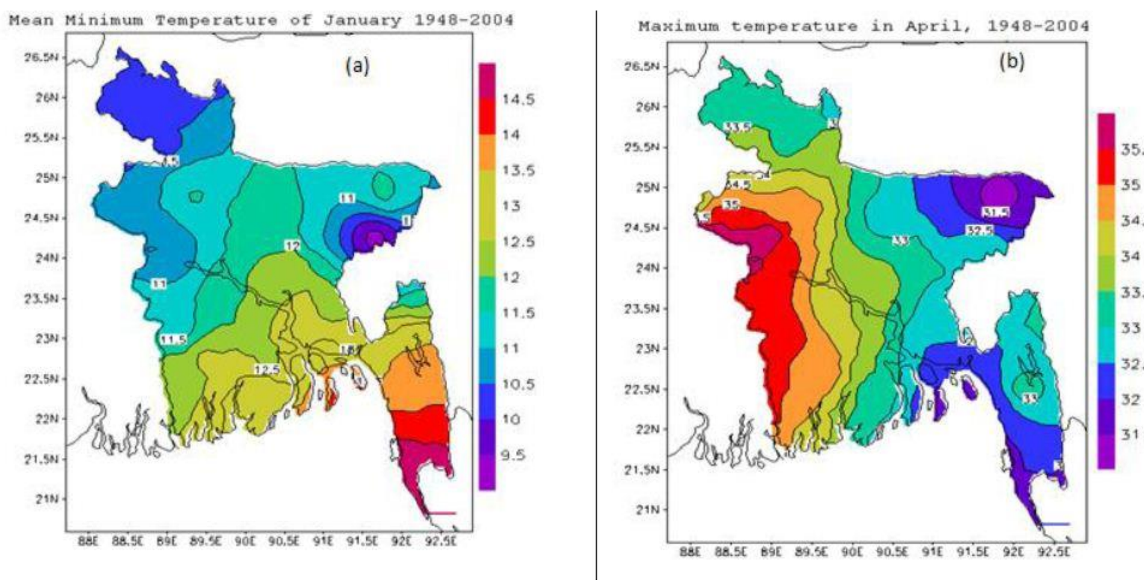

Figure 4: Geographical distribution of climatology of the minimum and maximum temperature in (a) January and (b) April[16]

The spatial distribution of temperature shows that the coastal zone is relatively warmer in the winter and the thermal gradient is positive towards south [Figure3(a)].The temperature is very high in the central western part of the country which extends up to the western coastal zone, whereas the eastern 5 coastal zone has a slightly milder temperature [Figure3(b)]. The maximum temperature in April is relatively low in the northeastern and southeastern part of the country. In the coastal area the temperature increases from east to west in the summer.

2.2.2 Precipitation Patterns

Bangladesh receives on an average 2,425 mm of precipitation/year, having a standard deviation of around 286 mm. Most of the precipitation occurs in the monsoon season (June-September) amounting to 1,750

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[15] Bangladesh Delta Plan 2100; Climate Change, August 2015
[16] Bangladesh Delta Plan 2100; Climate Change, August 2015

mm which is 72% of the total annual precipitation. The pre-monsoon season receives about 17% of the annual precipitation. The post-monsoon season occupies 9.1% of the annual precipitation. The winter is relatively dry and receives only 1.5% of the annual precipitation.[17]

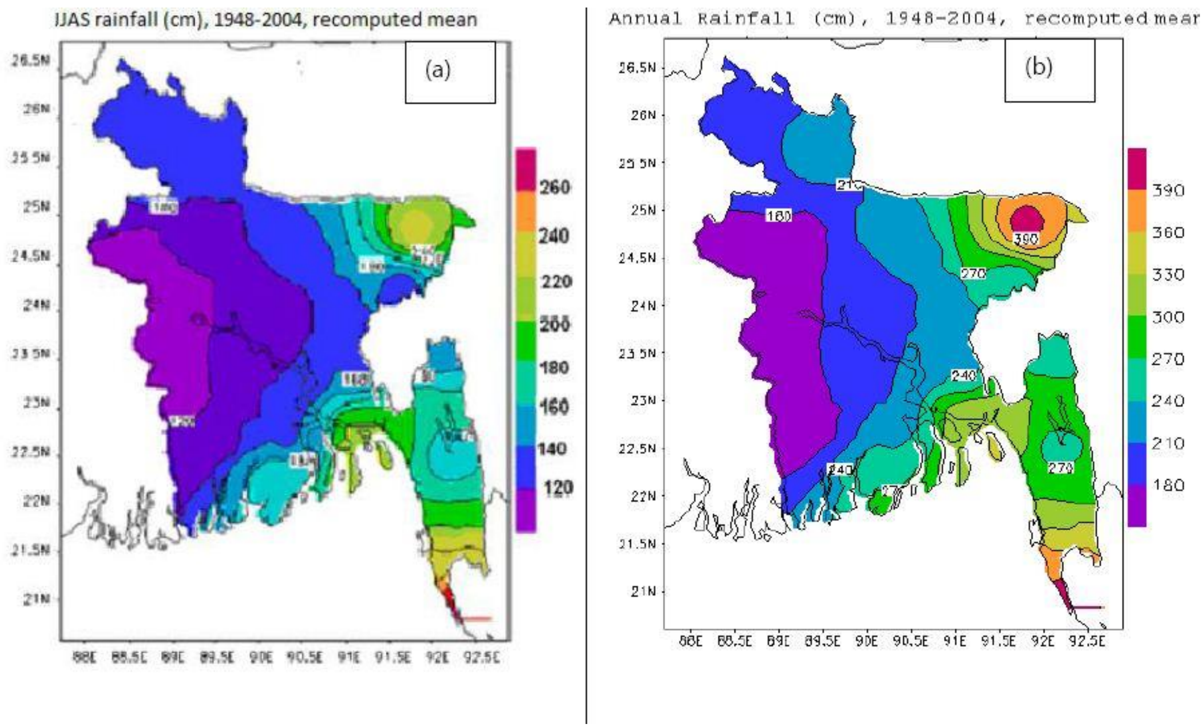

Figure 5: Distribution of monsoon precipitation (a), and annual precipitation (b) in cm[18]

The geographical variation of annual and monsoon precipitation is large in Bangladesh [Figure 4 (a,b)].The wettest parts of the country are the north-east and south-east where monsoon precipitation is around 2,000-2,800 mm and the total annual precipitation between 3,000 and 4,000 mm.[19] Relatively low precipitation is obtained in central-western Bangladesh which is oriented in the north–south direction. The low precipitation area bulges towards central Bangladesh. The distribution pattern is more or less similar for both annual and monsoon. The geographic distribution of annual precipitation shows that the coastal zone experiences around 1800-4000 mm of precipitation, but it is relatively higher over the southeastern coastal zone and gradually decreases towards the west.[20] The deficit and excess precipitation from normal becomes critical causing droughts and floods. Low pre-monsoon and monsoon precipitation and high temperature in these seasons have caused the western part of delta to become highly drought prone. Excessive precipitation over Bangladesh and in the upper catchment of the Ganges Brahmaputra and Meghna (GBM) river system causes devastating floods. The floods of 1974, 1988, 1998 and 2007 are worth mentioning. Further reference is made to the baseline studies on water resources and disaster management.

[17] Bangladesh Delta Plan 2100; Climate Change, August 2015
[18] Bangladesh Delta Plan 2100; Climate Change, August 2015
[19] Bangladesh Delta Plan 2100; Climate Change, August 2015
[20] Bangladesh Delta Plan 2100; Climate Change, August 2015

2.2.3 Extreme Weather Events

During the years 1797 to 1991, Bangladesh has been hit by 59 severe cyclones, 32 of which were accompanied by storm surges.[21] A tropical cyclone forming in the Bay of Bengal has a lifetime of one week or longer. The height of the surges is limited to a maximum of 10 meters in the bay. When propagating into the shallower inland coastal areas, the heights of these waves are further reduced. The frequency of a wave (surge plus tide) with a height of about 10 m is approximately once per 20 years. A storm surge of approximately once in 5 years has a height of about 7 m (surge plus tide). Moreover Storm and tidal surges can push saltwater further up Bangladesh's freshwater system, creating salinity issues almost 100 km inland. Cyclones can also aggravate water problems by damaging household latrines, thus increasing the risk of freshwater contamination and water-related illnesses (Shameem et al. 2014; Ahmeda et al. 2013).

Devastating cyclones hit the coastal areas of Bangladesh almost every year usually accompanied by high-speed winds, sometimes reaching 250 km/hr or more and 3-10 m high waves, causing extensive damage to life, property and livestock. Most of the damages occur in the coastal regions of Khulna, Patuakhali, Barisal, Noakhali and Chittagong and the offshore islands.

The storm surges that accompany the cyclones of the Bay of Bengal cause more destruction in the coastal areas and offshore islands of Bangladesh than the very strong winds that are associated with the cyclones. In the Meghna estuary, the 1970 Cyclone (Nov 12-13) with cyclonic surge of 3.05m to 10.6m high with wind speed of 222 km/h occurred during high tide causing most appalling natural disaster claiming 0.3 million human lives. On the 29 April 1991, a devastating cyclone hit Chittagong, Cox's Bazar, Barisal, Noakhali, Patuakhali, Barguna and Khulna along with tidal bore of 5-8m high with wind speed of 240 km/h which killed 150,000 human beings, 70,000 cattle head, and the total loss was about BDT 60 billion. Cyclonic storm Aila in 2009 was one of the worst natural disaster to affect Bangladesh. Torrential rains from Aila resulted in 190 fatalities and atleast 7,000 injuries across the Khulna and Satkhira districts. Approximately 9.3 million people were affected by the cyclone, of which 1 million were rendered homeless. This area is also constantly threatened by flooding.

2.3 Socioeconomic Condition

2.3.1 Population

The last official census of Bangladesh was carried out in 2011, according to which the population stood at 142 million. World Bank reported that, the population of Bangladesh was 161 million in 2015 and the average population density for the country was 1237 people per sq. kilometer which ranked 10th in the world. This high density is partly due to a rapid population boom that occurred in Bangladesh in the latter part of the 20th century. The coastline is of 734 km involving coastal and island communities of about 50 million people, nearly one-third of the total population of Bangladesh. The coastal zone covers 19 out of 64 districts facing or in proximity to, the Bay of Bengal, encompassing 153 Upazilas (MoWR, 2006). Out of

[21] Bangladesh Meteorological Department

these 19 districts, only 12 districts meet the sea or lower estuary directly. The coastal zone covers 47,201 square kilometer land area, which is 32% of total landmass of the country (Islam, 2004). Pramanik (1983) has divided the Bangladesh coastal zone into three regions namely; eastern, central and western coastal regions (Hossain and Hossain, 2008).

Population density in the eastern coastal districts (i.e. Chittagong, Cox's Bazar, Noakhali) is 1136 per sq.km, while in the Central coastal districts (i.e. Jalokathi, Pirojpur, Barisal, Bhola, Barguna, Patuakhali) the population density is 630 per sq.km and 475 per sq.km in the western coastal districts (i.e. Khulna, Satkhira, and Bagerhat).

2.3.2 Economic Status

Although the country has made considerable progress over the last few decades in growing the country's economy, with an average GDP growth rate of 5.72% since 1994 that peaked in 2016 at 7.05%, much of the population still finds itself below the poverty line. Additionally, while the percentage of the population in poverty has decreased in the last decade, the percentage of those in extreme poverty has remained the same.

Along with the Rangpur area, the southwest of Bangladesh is amongst the poorer regions of the country. About 16-35% of people living in Khulna are considered to be extreme poor; whereas in Barisal the percentage of extreme poor ranges from 6% of less in the southern most districts, and more than 35% in the city[22].

The economy of Khulna is predominantly agricultural. But its economy is also dependent on the Sundarbans and Mongla port. According to the current agriculture census the total holdings of the district is 503 thousand of which 41.31% holding are farms those produce varieties of crops, namely local and HYV paddy, wheat, jute, vegetables, spices, pulses, oilseeds, sugarcane and others. Various fruits like mango, banana, Jackfruit guava, coconut and betel nut etc. are grown. Fish of different varieties abound in the district as in other parts of the country. Varieties of fishes caught from rivers, tributaries, channels and creeks and even from paddy field during the rainy season. Besides crops, livestock and fishery are main source of household income. There are a number of Jute mills which plays a vital role in the economy. The status of nonagricultural activities are low in the district. The following table based on the 2001-03 Census of Non-farm Economic Activities indicates the broad types of Non-farm Economic Activities that are developing in the district.[23]

The rural economy of Satkhira is predominantly agricultural. Out of total 436,178 holdings 252,036 were farm holdings and they produce varieties of crops, namely, local and HYV rice, vegetables, spices, pulse and others. Fruits available in the district are banana, jackfruits, papaya, guava, olive etc. Besides crops, fishery and forestry are other sources of household income. Prawn is one of the main export items of Bangladesh, which is abundantly available in the district. Prawn farming in the coastal area is the most important economic activities of the households. The district is very rich in forest resources. The Sundarban is another source of income of the people of Satkhira district.[24]

[22] ICCCAD, March 2017
[23] BBS Census 2011
[24] BBS Census 2011

2.3.3 Gender roles

Bangladesh ranks 111th on a Gender Inequality Index (GII) amongst the 187 developed by the United Nations Development Programme (measured by the quality of reproductive health, the degree of empowerment, and women's economic status in the country). Gender inequality in Bangladesh arises from various societal and cultural norms that impact women's day to day activities as well as their adaptive capacity to climate change.

In the southwest coastal region, women's activities are assigned based on gender roles. Whereas men often leave the house for income generating activities, women take care of the domestic space and tend to what is known as "reproductive labor" as oppose to "productive labor". Women are in charge of ensuring safe drinking water for their families, which can often mean having to travel long distances to access a relatively clean water source. Additionally, women have less decision-making power and are often rendered immobile at the onset of an environmental hazard (while husband and sons often migrate elsewhere to look for work)[25].

2.4 Targeted Districts – Phase I: Khulna and Satkhira

2.4.1 Khulna District

Khulna district was established in 1882. The total area of the zila is 4394.45 sq. km. (1696.70 sq. miles) including 2348.55 sq. km. (906.78 sq. miles) reserve forest area. Sundarbans, the largest mangrove forest of the world, occupies 166814 hectares of this zila. It is located in between 21°41' and 23°00' north latitudes and between 89°14' and 89°45' east longitudes. It is bounded by Jessore and Narail zilas on the north, Bhairab River and Bagerhat zila on the east, south by the Bay of Bengal and west by Satkhira zila. [26]

Table 7: Demographic Information of Khulna District (BBS, 2011)

Area (Km^2)	# of Upazila	# of Municipality	# of Union	# of Mouza	# of Village	Population		Density (per sq. km)	Literacy Rate (%)
						Urban	Rural		
4394.45	9	2	69	751	1123	777588	1540939	528	60.1

Table 8: Upazila wise Information of Khulna District (BBS 2011)

Name of Upazila	Area (Km^2)	Union	Mouza	Village	Population	Density (per sq km)	Literacy Rate (%)
Batiaghata	248.31	7	127	172	171691	691	54.9

[25] ICCCAD, March 2017

[26] BBS 2011

Name of Upazila	Area (Km^2)	Union	Mouza	Village	Population	Density (per sq km)	Literacy Rate (%)
Dacope	991.56	10	26	97	152316	154	56
Dighalia	77.16	4	29	43	115585	1498	54.3
Dumuria	454.23	14	189	240	305675	673	52.6
Koyra	1775.40	7	71	133	193931	109	50.4
Paikgacha	411.19	10	149	212	247983	603	52.8
Phultala	56.83	3	18	29	83881	1476	59
Rupsa	120.15	5	64	78	179519	1494	58.2
Terokhada	189.49	6	32	99	116709	616	48.5

Khulna is the third largest economic centre in Bangladesh and Mongla, one of the major sea port of the country is situated in Khulna. The major sectors are jute, chemicals, fish and seafood packaging, food processing, sugar mills, power generation and shipbuilding. The region has an Export Processing Zone which has attracted substantial foreign investment. This infrastructure plays a vital role in the city's economy, which also depends upon fishing and salt industries. Main sources of income are agriculture 34.90%, non-agricultural labourer 6.22%, industry 3.51%, commerce 19.60%, transport and communication 5.17%, service 18.27%, construction 1.99%, religious service 0.21%, rent and remittance 0.78% and others 9.35%.[27]

2.4.2 Satkhira district

The total area of the district is 3,817.29 sq. km. (1473.86 sq. miles) of which 1632.00 sq.km. is under forest. It is located between 21º36' and 22º54' north latitudes and between 88º54' and 89º20' east longitudes. The zila is bounded on the north by Jessore district, east by Khulna district, south by the Bay of Bengal and west by West Bengal state of India.

Table 9: Demographic Information of Satkhira District (BBS, 2011)

Area (Km^2)	# of Upazila	# of Municipality	# of Union	# of Mouza	# of Village	Population		Density (per sq km)	Literacy Rate (%)
						Urban	Rural		
3817.29	7	2	79	916	1440	197616	1788343	520	52.07

[27] Banglapedia, 2016

Table 10: Upazila wise Information of Satkhira District (BBS 2011)

Name of Upazila	Area (Km^2)	Union	Mouza	Village	Population	Density (per sq km)	Literacy Rate (%)
Assasuni	374.81	11	143	241	268754	717	49.83
Debhata	173.21	5	59	125	125358	724	54.82
Kalaroa	231.42	12	112	136	237992	1028	50.94
Kaliganj	333.78	12	243	254	274889	824	51.78
Satkhira Sadar	398.57	14	119	237	460892	1156	56.51
Shyamnagar	1968.23	13	127	218	318254	162	48.62
Tala	337.24	12	150	229	299820	889	50.88

Most of the peoples of southern part of Satkhira depend on pisciculture, locally called *gher*. There are 86 dairies, 322 poultry farms, 3046 fisheries, 3650 shrimp farms, 66 hatcheries and one cattle breeding centre. The main exports are shrimp, paddy, jute, wheat, betel leaf, and leather and jute goods.[28] Main sources of income are agriculture 62.56%, non-agricultural labourer 4.33%, industry 1.51%, commerce 16.23%, transport and communication 3.03%, service 4.86%, construction 1.01%, religious service 0.19%, rent and remittance 0.34% and others 5.94%.[29]

[28] Wikipedia
[29] Banglapedia

3. Drinking Water Sources, Supply and Access

3.1 Freshwater Availability

In most of the areas of Khulna and Shatkhira district, tube-well is the main source for drinking water (Table 1 & 2). There are areas where tube-wells are not successful to produce low saline water. Moreover, failure of existing tube-wells to yield water of satisfactory quality is quite frequent. As a result, people use contaminated water from unprotected rivers, ponds, and shallow wells. Rainwater harvesting is also popular in many areas. Piped water supply is available only in major urban centers in the coastal area covering a small percentage of total population. (BBS 2011)

Table 11: Upazila Wise source of Drinking Water of Khulna District (BBS 2011)

Name of the Upazila	Tubewell (%)	Tap (%)	Others (%)
Batiaghata	96.4	0.1	3.5
Dacope	30.6	0.7	68.7
Dumuria	99.9	0.1	0
Dighalia	97.8	1.4	.8
Koyra	44.3	0.3	55.4
Paikgacha	62.4	1.6	36
Phultala	96.9	1.4	1.7
Rupsa	97.7	0.7	1.6
Terokhada	96.8	0.1	3.1

Table 12: Upazila Wise source of Drinking Water of Satkhira District (BBS 2011)

Name of the Upazila	Tubewell (%)	Tap (%)	Others (%)
Assasuni	71.5	1.3	27.2
Debhata	94.4	2	3.6
Kalaroa	97.6	0.6	1.8
Kaliganj	77.8	14.6	7.6
Satkhira Sadar	83.1	14.3	2.6
Shyamnagar	43	0.8	56.2
Tala	95.2	0.6	4.2

3.2 Water Quality

The main issues surrounding water quality are microbial pathogens, arsenic (As) in groundwater and salinity. Although a significant issue, bacterial contamination of water is not addressed here. For decades, the widespread contamination of groundwater by As in Bangladesh has been recognized as a severe problem (Ahmed et al. 2006; Ahmed 2011). Although it is naturally occurring, arsenic contamination is a continuing public health issue in Bangladesh, potentially affecting millions of people (Chowdhury 2010; BBS 2011). Salinity has been recognized as a significant water problem in coastal Bangladesh for some time, as a result of both man-made and natural causes (Uddin & Kaudstaal 2003; Rahman & Bhattacharya 2006; Mahmuduzzaman et al. 2014).

A study paper titled "Salinity Status in Groundwater A study of Selected Upazilas of Southwestern Coastal Region in Bangladesh[30] " provides information about present status of groundwater salinity condition in the study area which covers nine upazillas of Khulna, Jessore and Satkhira districts with an area about 1534 km2. The assessment was based on the outcomes of the limited data collected during 11-23 December, 2011 on a pilot basis of Khulna region. The study reveals that groundwater of southwestern coastal region is mostly saline. This is more prominent in the shallow aquifer. It was found that about 18.37% SHTWs had salinity more than 1000 ppm. The salinity in SHTWs in the upazilas of Jessore and Satkhira was less than 1000 ppm. The situation was found worse in Paikgacha and Batiaghata upazilas of Khulna. In the study area about 5.6 % DHTWs showed salinity above 1000 ppm. In contrast, almost all DHTWs in Paikgacha exceeded salinity level. The percentage of DHTW containing salinity more than 1000 ppm in the upazilas of Tala, Dumuria and Batiaghata were 11.1, 5.41 and 2.27 respectively.

Another important issue is Arsenic. The geographic distribution of Arsenic vary greatly from one district to another. The greatest concentration is observed in the south and south-east and the smallest concentration in the north and north-west of Bangladesh. The regional trends are more clearly seen in the smoothed map of National Hydrochemical survey (Figure 1). Average concentration of Arsenic found in Khulna district is approximately 85µg/L.

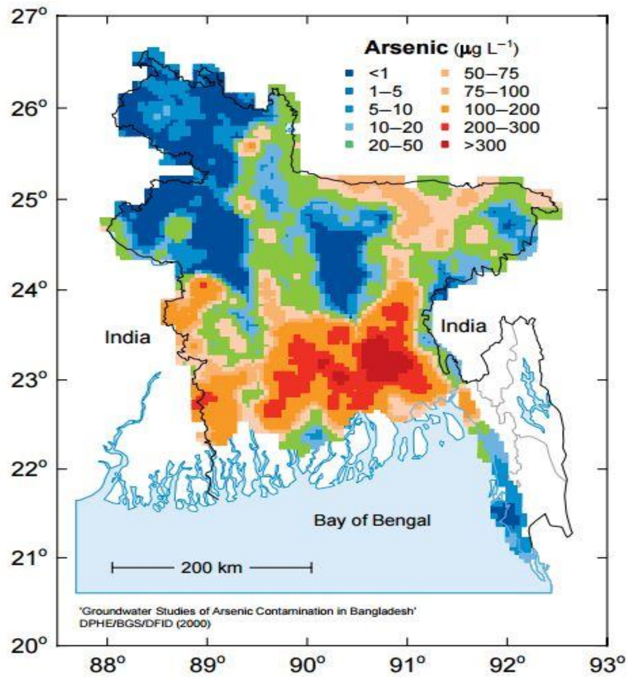

Figure 6: Map of smoothed groundwater arsenic concentrations from the national Hydrochemical Survey

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[30] Md. Rezaul Hasan, Md. Shamsuddin and A.F.M. Afzal Hossain, "Salinity Status in Groundwater: A study of Selected Upazilas of Southwestern Coastal Region in Bangladesh," Global Science and Technology Journal, Vol. 1, No. 1, July 2013.

4. Climate Change Impacts on Coastal Drinking Water Sources, Supply and Access

The coastal areas of Bangladesh are highly vulnerable to the impacts of climate change, including from cyclones and tidal surges. The impacts of climate change have had a significant impact on available potable water, on both surface and groundwater in coastal areas. The main climatic factors contributing to water scarcity in coastal areas are salinity in surface and groundwater due to sea level rise and tidal surges, and variation in precipitation pattern. Hence, consideration of possible impacts of climate change, observed and projected, on water sources is of prime importance when selecting appropriate technologies in coastal area. In this chapter, a review of available information from secondary sources on impact of sea level rise, rainfall, and natural hazards on water sources in coastal areas have been presented.

4.1 Impact of change in precipitation trends on coastal drinking water sources, supply and access

An overall increase is observed in all the seasons in the mean seasonal rainfall and found to be maximum during the pre-monsoon (MAM) and monsoon (JJA) season by around 100 mm increase in the mean seasonal rainfall. Increase in the mean seasonal rainfall is seen particularly in the coastal regional stations of Sitakunda, Patuakhali, Kutubdia and in Khulna in the range of 1.2 to 2.1 mm/year. Decrease in the pre-monsoon (MAM) seasonal rainfall is evident in the coastal regional stations of Bhola and Madaripur in the range of 3-19 mm/year decrease in the mean seasonal rainfall. Increase in the monsoon (JJA) rainfall is observed in the coastal district stations of Kutubdia, Mongla, Sitakunda and in Teknaf stations in the range of 21-42 mm/year increase in the mean seasonal rainfall. (CEGIS, 2011)[31]

Since the variation of rainfall will be sensitive in terms of geographic locations, many areas will endure water logging, turbidity as well as sedimentation problems in the country. Availability of fresh water will decrease due to salt water intrusion and regional rainfall patterns. Occurrence of water-borne diseases will increase while water treatment and water supply infrastructure will face challenge. Rainfall is one of the most major components for recharging groundwater. Thus, water options could be experienced on seasonal water depth variations in terms of layer status.

Meanwhile, there is acute water stress in some parts of the region, where surface water and groundwater have shown an alarming situation vis-a-vis irrigation and safe drinking water. Increased rainfall brings water borne infectious diseases from one place to another through runoff whereas scanty rainfall often leads to desertification in an area. A number of people will lose year-round access to safe drinking water due to irregular rainfall. Thus, recurrent costs for water supply and public health will increase. Bangladesh will be at high risk from climate change induced moisture stress and resulting phonological drought impacts. Given reductions in mean dry season rainfall it is likely that dry spells may increase/lengthen with negative consequences for water availability/soil moisture.

In a study conducted by IUCN in 2015, areas with less or equal to 380 mm throughout the dry season (Nov-May, NWMP) has been termed as the rainfall stressed area. Inadequate rainfall means that there is insufficient water for the ground water and surface water to recharge which consequently has negative effect on the provision of water supply. Water is used for multiple purposes such as drinking, domestic,

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[31] Climate Change Vulnerability of Drinking Water Supply Infrastructure in Coastal Areas of Bangladesh, IUCN 2015

industrial use, environmental use etc. So lack of water may lead to health problems. The rainfall stressed areas have been identified by analyzing the rainfall data of 34 BMD stations with a time range of 1948 to 2008. The districts identified as rainfall stressed are Jessore (99.64%), Satkhira (63.29%), Khulna (57.33%), Narail (55.96%) and Bagerhat (16.34%).[32]

4.2 Impact of of Cyclones and Tidal Surges on coastal drinking water sources, supply and access

Bangladesh is affected with hazards of different types such as flood (river flood and flash flood), drought, cyclone, storm surge, erosion, salinity intrusion, earthquake etc. The occurrence, extent and intensity of these hazards vary from region to region of the country. But the coastal morphology influences the propagation of storm surges in those areas. Inundation due to flooding and storm surge differs based on the land elevation and surface form. In the last 200 years more than 70 cyclones have hit the coast damaging life and properties.

In the coastal zone, half of the area is threatened with cyclonic storm surge. Around 45% area and 4% area are threatened by storm surge of more than 1 metre and less than 1 metre height respectively. There are 13 districts which are vulnerable to storm surge of more than 1 metre namely Bagerhat, Barguna, Barisal, Bhola, Chittagong, Cox's Bazar, Feni, Jhalokhati, Khulna, Lakshmipur, Noakhali, Patuakhali, and Pirojpur districts. Again, for a storm surge of less than 1 metre, the districts at risk are Bagerhat, Barisal, Khulna, Lakshmipur and Pirojpur.[33]

4.2.1 Impact on water related infrastructure

Devastating cyclones hit the coastal areas of Bangladesh almost every year usually accompanied by high speed winds, sometimes reaching 250 km/hr or more and 3-10 m high waves, causing extensive damage to life, property and livestock. Cyclonic storm Aila in 2009 was one of the worst natural disaster to affect Bangladesh. Torrential rains from Aila resulted in 190 fatalities and at least 7,000 injuries across the Khulna and Satkhira Districts. Approximately 9.3 million people were affected by the cyclone, of which 1 million were rendered homeless[34]. According to local people, the coastal embankment was badly damaged during the cyclone Aila causing intrusion of salt water into the fresh water pond in the Union. The effect of Aila and saltwater intrusion due to sea level rise on surface water sources, e.g., ponds, left a very limited number of fresh water ponds as drinking water source for people living in many villages in these districts.

4.2.2 Impact on water ponds, ground and surface water

Cyclone Sidr in 2007 and Aila in 2009 both are the strongest cyclones in Bangladesh. The storm caused large-scale evacuations and deaths. Such frequent storms brought much saline water inland and ruined the rice fields that people depend on for employment and food. Frequent natural disasters mean that the traditional ponds or surface water bodies become inundated with sea water making these unsuitable for any form of human use. The people in Satkhira received the highest amount of sufferings from drinking

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[32] Climate Change Vulnerability of Drinking Water Supply Infrastructure in Coastal Areas of Bangladesh, IUCN 2015

[33] Climate Change Vulnerability of Drinking Water Supply Infrastructure in Coastal Areas of Bangladesh, IUCN 2015

[34] *Integrated Regional Information Networks, 2009*

water shortage soon after Aila attacked.[35] Aila devastated all the drinking water sources (ponds and tube wells). High tidal surges, during the disaster, contaminated all fresh water sources with polluted saline water. According to newspaper reports, the freshwater crisis had intensified after cyclone Aila hit in 2009 when the polders in the coast were damaged and the region was submerged by saline water. District-wise Aila damage assessment of water infrastructure conducted by DPHE suggested that among the affected districts, Khulna and Satkhira were the worst affected areas in terms of Water and Sanitation facilities where 278 PSFs were damaged. The situation was acute in Gabura and Burigoalini union of Satkhira district where most of the drinking water sources were damaged. Many people were forced to drink such polluted water since they did not have any other option.

4.3 Impact of salinity intrusion due to sea level rise

The intrusion of saline water from the sea into the inland is hazardous for the environment in many water. Most importantly, saline water contaminates sweet water resources rendering it unusable for drinking. Moreover, salinity damages the fisheries, crops and the Sundarbans. The biodiversity of the Sundarbans is changing due to increased level of salinity. About 14698 sq. km area is exposed to high salinity of 1 ppt under zero sea level rise. Severely affected districts are Bagerhat, Bhola, Chittagong, Cox's Bazar, Jessore, Khulna, Lakshmipur, Narail, Noakhali and Satkhira having more than 15% area under 1 ppt saline zone.[36]

Sea level rise and salinity intrusion will reduce fresh water options where already 53% of the area has been affected by salinity. This could increase expenses for water treatment mechanism. Saline water intrusion into groundwater will be increased due to low elevation as well as hydraulic structures. In turn, access to safe drinking water options can be dramatically reduced. This changed physical environment will affect public health issues and coastal livelihoods. The salinity front will move towards inland from the south of Bangladesh with SLR and it will be further aggravated if the fresh water flows from upstream declines. Low saline areas (0-1ppt) will decrease from 11% to 9% and 4% by 2050 and 2100 respectively, whereas high saline area (20ppt-25ppt) will increase from 13% to 16% and 18% by 2050 and 2100 respectively.[37] Based on model predictions, the population exposed to high salinity (>5 ppt) is expected to increase to 13.6 million in 2050 and to 14.8 million in 2080. (CEGIS, 2006) Again, according to another estimate, the area under 1 ppt salinity line will increase to 17.5% (1 ppt) and area under 5 ppt salinity will increase to 24% by 2050. So, there will be around 7% increase in area under 5 ppt salinity levels. (CEGIS, 2011) A study by the World Bank (2010) predicted that with a sea level rise of 62 cm, the cyclone-induced storm surges will inundate an additional 15 % of the coastal area by the year 2050.

4.4 Social impacts

As shortage of safe drinking water is likely to become more pronounced, especially in the coastal belt, this will impose hardship on women, who are primarily responsible for collecting drinking water for their family. In 90% of the households, women collect drinking water. They must travel a long distance (2-3 km) by crossing rivers, kacha road, Bamboo Bridge to collect water which requires significant time (1-2 hrs) and effort. Sometimes they have to pay for transport when it is not possible to walk such long distance

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[35] Dasgupta, et al., 2011

[36] Climate Change Vulnerability of Drinking Water Supply Infrastructure in Coastal Areas of Bangladesh, IUCN 2015

[37] Climate Change Vulnerability of Drinking Water Supply Infrastructure in Coastal Areas of Bangladesh, IUCN 2015

and this results in further marginalization of the poor and women headed households. Women having children under 5 years old also suffer as they have to leave their children at home while collecting water from remote places. Climate change is likely to adversely affect women more than men. Increasingly saline drinking water may also result in health hazards especially for the pregnant women.

The need of collecting water is a significant source of stress and tension within households, especially in times of water scarcity. Secured access to water has a positive impact on gender relations and family well-being. Ensuring water access has a direct impact on women's time and workload; women can save at least 1-2 hours daily, if the water source is made available near their homes in the dry season. Lack of easy access to safe drinking water sources considerably increases the risk of the incidence of waterborne diseases. This has negative impacts on women as they are the primary caregivers when a household member is sick.

4.5 Health implications

The changes of the climate system or climate induced hazards pose direct and indirect impacts on water resources and human health in most of the areas of the country and especially in the coastal areas. The water resources and safe water supply systems are threatened by both climatic and non-climatic factors. A number of climate factors or climate induced hazards including cyclone and storm surges, floods, droughts, saline intrusion, erratic behavior of rainfall along with non-climate factors such as arsenic contamination, industrial pollution affect both surface and groundwater resources. On the health issues, incidences of a number of diseases including diarrhea, malaria, dengue, kalazar, HIV/AIDS, enteric fever, anthrax, avian influenza, Nipah virus infection, leptosporiasis, acute respiratory infections (ARI) in recent years are alarming.[38] Of them, dengue, malaria, diarrhea, Kalazar have already been referred as climate sensitive diseases.[39] In addition, cholera is probably a re-emerging infectious disease in the country which is also sensitive to climate parameters (temperature and sun shine).[40]

Health risk due to climate change is predicted to increase all over Bangladesh. The country may be affected mostly by vector and waterborne diseases. Studies suggest that a number of diseases and health problems including malaria, dengue, Kalazar, cholera, malnutrition and diarrheal diseases are associated with climate related factors such as temperature, rainfall, floods, droughts etc. These were also found to be associated with non-climatic factors including poverty, lack of access to safe drinking water and sanitation and poor sewerage system etc.[41] According to a study, the tendency of diarrhoea (32%) and dysentery (44%) is high in the affected areas because the majority percentage used pond water as their main drinking water sources without any further treatment and poor sanitation system.[42] Some of the recent research findings on climate change and health issues in Bangladesh are stated below:

- Seasonal peak of Escherichia coli diarrhea coincides with the time when food is contaminated due to higher bacterial growth caused by high temperature.[43]
- Increase in rotavirus diarrhea in Dhaka by 40.2 percent for each 1°C increase of temperature above 29°C (Hashizume et al. 2008).
- Increase of cholera incidences is associated with increase of sea surface temperature (Feldacker 2007).

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[38] Impact of CC on Water Resources and Human Health; Md. Golam Rabbani, Saleemul Huq and Syed Hafizur Rahman

[39] Confalonieri et al. 2007

[40] Wagatsuma et al. 2003; Confalonieri et al. 2007

[41] Cruz et al. 2007

[42] Impact of CC on Water Resources and Human Health; Md. Golam Rabbani, Saleemul Huq and Syed Hafizur Rahman

[43] Rowland, in Shahid 2010

- Number of non-cholera diarrhea cases in Dhaka increases with higher temperature, particularly those individuals at a lower socioeconomic and sanitation status.[44]

Moreover, consumption of sodium through drinking saline water forms a significant part of the total sodium intake in these areas.[45] The association between excessive sodium intake and increased risk of hypertension is widely known (e.g., WHO 2012). Furthermore, Khan et al. (2014) have found an association between drinking water sodium and preeaclampsia (a condition in pregnant women characterised by high blood pressure) in a salinity prone area in southern Bangladesh. People residing in highly vulnerable coastal segments may have hypertension/high blood-pressure attributable to drinking water salinity.[46]

4.6 Impacts on Khulna and Satkhira Districts

4.6.1 Khulna District[47]

The district Khulna is characterized by increased frequency of disasters, especially cyclones, increased salinity, both in drinking water and impacts on agriculture, and increased frequency of flooding and inundation from high tide, tidal surges, river erosion, and embankment erosion. Flooding is reported to be caused by a variety of factors, sometimes together and sometimes separately, including heavy rain (more frequent heavy rain events), high tides (the nature of tides were described as having changed, and that now during high tide times the sea water is raised even higher, flooding houses, fields, and roads), tidal surge (sometimes discussed as linked to storms and sometimes discussed more like very high tides and not part of storm events), river erosion (collapse of land and/or embankments leading to inundation from the river), and as a result of cyclones and storms. Flooding also ranged from localised flash flooding (such as from high tide) through to prolonged periods when whole areas were underwater for many weeks and months (such as from tidal surges or destruction of embankments). Key consequences cited across these different varieties of flood events are:

- Damage to buildings and infrastructure – including houses, schools, roads, and fields –sometimes leaving people homeless.
- Buildings and fields flooded for considerable periods of time – sometimes leaving people homeless.
- Children unable to go to school.
- Drinking water crisis – fresh water ponds flooded, Pond Sand Filters and other water sources contaminated also.
- Crop losses and livestock deaths.
- Danger of drowning for children.
- Many people dying as a result of tidal surge.
- Child marriage increases for poor families trying to recover from impacts of flood events.
- Disruption to all types of services, especially education, health treatment, businesses, communications, and physical access to markets/meeting travel needs.
- Financial crisis, especially for poor families.
- Increased water-borne and skin diseases.

[44] Hashizume et al. 2008
[45] Hoque and Butler 2016
[46] Houque et Al. 2016
[47] Climate Change Study Book by UNICEF Bangladesh, May 2016

Increased salinity after cyclones had always been a problem, but one that people previously eventually recovered from. However, they felt that increased salinity was now a daily problem because of the increased impacts of tidal surge. It was not just water surface water supplies that were suffering salinity; both groundwater and cropland were also described as saline, with the result that they felt they were suffering a constant crisis of saline water and infertile land.

The consequence of the salinity has been perceived as a big crisis for drinkable water, not just after disasters but all the time. Water had to be collected from further away, and less was available even there. Children and adolescents felt that there was more malnutrition and diseases because of this water crisis. They also felt that the land wasn't producing as much crop because of the salinity of the soil and water. They reported that it affected the availability of food and the overall economic wellbeing of their family. Vegetable, rice, and fruit production were reported to be declining every day, blamed on decreasing fertility of soil due to not enough rain to wash away the salinity of the soil, and to replenish the ground water and surface water used in crop production. The trees were also reported to be dying, particularly coconut trees and some local varieties of fruit, which were now no longer available for the children to eat.

Cyclones are of highest concern to all the adult community groups, not just for the severity of their impacts, but because it was felt that they have become more frequent, therefore it is no longer just a case of the severity of the impacts, but the cumulative impacts as there is less time to recover before the next one. They said that every year now a cyclone is formed in the bay, and whilst the cyclone does not always reach land and impact on them, there are more warnings and more worry for 6-10 days that a cyclone may come. When cyclones do come there are multiple impacts including tidal surge, river erosion, and embankment erosion/destruction. Houses, schools, school materials, crops, trees, roads, sanitation systems, and fish farms are damaged or destroyed. Human lives are lost, as are cattle and other animals. Assets are lost, both through the disaster itself, and through theft if people have gone to cyclone shelters or other places. Tube wells, ponds, and rivers are filled with saline water. There are diseases, especially diarrhoea diseases. Children can't go to school, in some cases schools were closed for about 2 months, and their education is hampered.

4.6.2 Satkhira District[48]

It is evident that significant land-cover change happened in Satkhira district between 1999 and 2012. Water cover increased because shrimp culture ponds increased (suggested by a ground truth survey). The built-up and bare land category also increased due to the secondary effects of various disasters. For example, the area is surrounded by coastal embankments which create water logging during high tide. This water logging becomes more prolonged because natural drainage systems are blocked due to land grabbing and siltation on the riverbeds. As a result, salinity intrusion occurs in both agricultural land and other areas as well. Thus, most of the area has become unproductive for agricultural production due to long-term inundation by saline water resulting in increases in the bare land category. UN-HABITAT reported that because of high-intensity disasters, large parts of the region may become uninhabitable due to long-term inundation (UNHABITAT 2010). Decrease in crop land is clearly due to increases in shrimp culture, while the overall decrease in vegetation cover is attributed to both anthropogenic activities and natural disasters (Rahman et al. 2013). This evidence can explain the impact of the cyclone Aila in 2009 on the study area and the decreased trend of paddy production and overall vegetation. These decreases are likely associated with both natural disasters and anthropogenic activities. This analysis shows that due

[48] Natural disasters and land-use/land-cover change in the southwest coastal areas of Bangladesh Md Modasser Hossain Khan • Ian Bryceson • Korine N. Kolivras • Fazlay Faruque • M. Mokhlesur Rahman • Ubydul Haque, 2014

to various disasters (cyclone Aila and Sidr), overall income and agricultural production decreased temporarily among families dependent on agriculture. Akter and Mallick 2013 reported that an increased risk of tropical cyclones is likely to reduce incomes and standards of living among the tropical coastal communities (Akter and Mallick 2013). The study confirmed the similar findings reported following extreme disaster events like cyclones, drought, rainfall and major floods that could cause the spread of diseases (Epstein 1999; Milly et al. 2002). It also confirmed there was almost no crop production in 2009 due to salinity intrusion (Kumar et al. 2010), and in 2010, the crop production was also lower due to continued impact of salinity.

Most of the local tree species have become threatened and affected by various land-use/land-cover change outcomes such as water logging and increasing salinity (Rahman et al. 2011; Gain et al. 2007; Karim 2006). Salinity intrusion due to the presence of shrimp farms is another reason for destruction of trees, as the forest is cleared to cultivate shrimp (Haque et al. 2008). The salinity situation was worsened after cyclone Sidr in 2007 and cyclone Aila in 2009 (Khan et al. 2010). After the latest disaster (cyclone Aila in 2009), most of the freshwater sources were contaminated due to salinity intrusion and water logging (Kumar et al. 2010). Although high salinity levels in this region have existed for a long time, within the last four decades, the salinity of the study area has increased 3.02 % (Miah 2010). Construction of shrimp ponds and infrastructure for shrimp farms is one of the reasons behind the intrusion of saline water in the study area (Rahman et al. 2011).

An additional cause for increasing river and groundwater salinity is the upstream diversion (Farrakka barrage) in the Ganges in India (Gain et al. 2008; Mirza 1997; Rahman et al. 2011). Soil degradation happened as the salinity has increased in the soil and in neighboring water bodies, which in turn contributes to deforestation (Islam 2006). Prolonged shrimp farming increased soil salinity and acidity, and depleted soil to a variable degree and caused soil degradation (Ali 2006) to the extent that some farmers could no longer grow crops (Rahman et al. 2011). The shrimp farms also made the surrounding water unsuitable for domestic use and consumption for the people of that area and rendered the soil unsuitable for crop cultivation (Pouliotte et al. 2009).

The salinity intrusion has made the people dependent on rice imports from other parts of the country and subject to food insecurity and malnutrition (Islam and Ahmed 2001). Shrimp culture has also accelerated the process of eutrophication and pollution in the surrounding area from runoff or seepage of nutrients, release of sewage, use of veterinary products and from feed added to the ponds (Hoq 1999). Most of the native fish species have become endangered. It happened because the salinity level of both surface and ground water has increased (Gain et al. 2008). Besides, construction of coastal embankments degraded the natural breeding grounds, and fish habitats and natural fish production decreased (FAO 2005). Therefore, salinity intrusion significantly influences livelihood strategies of the people (Haider and Hossain 2013). People of the area suffered from lack of access to safe drinking water and sanitation facilities (Mallick and Vogt 2012; Rowsell et al. 2013). Shrimp cultivation negatively affected the ecological systems of the southwestern part of the country (Bush et al. 2010). Destruction of habitat and loss of biodiversity of fish species occurs when shrimp fry collectors catch fry from rivers adjacent to Sundarban, affecting the regional ecosystem (Islam and Ahmed 2001).

The Food and Agricultural Organization (FAO 2005) described the destruction of nearly 100 other species of flora and fauna, while shrimp fry are collected. Similarly, loss of species and habitats also resulted from land-use changes in upstream catchments (Black et al. 2011). Hence, habitat fragmentation by human interventions threatened the biodiversity of forested areas as well as elsewhere in the country (Khan et al. 2010). Irregular rainfall is also responsible for decreasing trends of fish species (Ahmed et al. 2012), as the fish species tend to lay eggs on streams created by showers. For the fish species, this recently fallen water is the best habitat for freshly hatched larvae. Any change in the occurrence of a thunder shower by a few days discourages female fish from laying eggs, thereby causing a net decrease in the fish population. This increasing salinity is worsened by occurrences of disasters like cyclones, storm surges and water logging and thus often significantly enhances the changes in land-use activities which encouraged shrimp farming, restricts rice cultivation, affects income and expenditure negatively, creates water crisis and decreases employment opportunities.

5. Past and Ongoing Efforts

5.1 Government-Led Programmes and Initiatives

DPHE is implementing a massive World Bank financed Project "Bangladesh Rural Water Supply and Sanitation Project (BRWSSP) covering 383 unions of 20 districts including Khulna and Satkhira (2012-2017). Under this project, 65 DHTWs, 520 RWHSs and 14 PSFs have been installed in different unions of Khulna and Satkhira districts.

5.2 Donor based Programmes and Initiatives

As per available information[49], there were four NGOs[50] with the support from international donors[51] have recently[52] (December 2016) completed their drinking water supply programmes in Shyamnagar upazila. The programmes were implemented targeting about a total of 3,500 community people, and facilitated communities to install and use number[53] of Reverse Osmosis (RO) plants, Rain Water Harvesting Systems (RWHS), and Pond Sand Filters (PSF) as safe drinking water sources.

Specific to unions under the upazila, where drinking water supply programmes were recently completed, a summary of the programmes is presented below in table 13:

Table 13: Drinking water supply programmes in Shyamnagar

Union	Implementing agency/NGOs	Target beneficiaries	Population covered	Technology options used	Period of programme
Gabura	IRW-B	Community people	180	RWHS	36 months
	Friendship	Community people	1,750	RO plants	48 months
	NGO-PH	Community people	1,800	RO plants	22 months
	Shushilan	Community people	900	DTW, RWHS	12 months
	GIZ	Community people	1,400	RO plants	18 months
Burigoalini	DAM	Community people	1,500	RO	18 months
	Shushilan	Community people	900	RWHS	12 months
Munshiganj	Shushilan	Community-institutions	1,716	RWHS, DTW	11 months
	IRW-B	Community people	3,480	DTW	12 months
	GIZ	Community-institutions	4,000	Mini PWSS	24 months
Ramjannagar	IRW-B	Community people	1,600	RWHS	36 months
Kaikhali	Madani Foundation	Community people	500	PSF	12 months
	Caritas Int.	Community people	1,000	PSF, Pond Ex.	24 months
	JCF	Community people	300	RWHS (Tank)	18 months
	GIZ	Community people	500	Mini PWSS	6 months

49 Source: WaterAid partner NGOs working/worked in the coastal districts (collected in March 2017)
50 Namely: 1) Shushilan, 2) Friendship, 3) NGO Forum for Public Health, and 4) LEDARS
51 Yet unknown
52 Period from exact time the programmes were started and ended-up by when is yet unknown
53 Yet unknown

Union	Implementing agency/NGOs	Target beneficiaries	Population covered	Technology options used	Period of programme
	Shushilan	Community-institutions	5,000	RWHS, PSF	36 months
Atulia	GIZ	Community people	800	Mini PWSS	18 months
	Shushilan	Community-institutions	6,500	RWHS, DTW	12 months
Padmapukur	GIZ	Community people	1,020	Mini PWSS	18 months
Kashimari	Shushilan	Community-institutions	2,000	DTW	36 months
	IRW-B	Community people	1,000	DTW	12 months
	Madani Foundation	Community-institutions	1,000	DTW	36 months

Similar NGOs, as stated above who were reportedly completed programmes, have also been continuing the implementation of several other/or similar donor[54] assisted drinking water supply programmes targeting rather an increased number (about 20,000) of community people of the upazila. Reportedly[55], they continue to support installing and ensuring community access to similar drinking water options i.e. RO plants, RWHS and PSF. However, these programmes are supposed to be ended up by December 2017.

Specific to unions under the upazila, where drinking water supply programmes are ongoing, a summary of the programmes is presented below:

Table 14: Union specific programmes

Union	Implementing agency/NGOs	Target beneficiaries	Population covered	Technology options used	Period of programme
Gabura	Broti	Community people	3,500	PSF	96 months
	Shushilan	Community people	500	PSF	11 months
	World Vision	Community people	Unknown	Unknown	48 months
Munshiganj	RDA Bogra	Community-institutions	4,032	Mini PWSS	120 months
	Shushilan	Community people	550	RWHS	36 months
	World Vision	Community people	Unknown	Unknown	48 months
Ramjannagar	Shushilan	Community-institutions	345	RWHS, PSF	36 months
	World Vision	Community people	Unknown	Unknown	48 months
Kaikhali	Shushilan	Community-institutions	5,000	RWHS, PSF	36 months
	World Vision	Unknown	Unknown	Unknown	48 months
Atulia	Shushilan	Community people	3,600	RWHS, PSF	96 months
	Shushilan	Community people	500	RWHS	36 months
Padmapukur	Friendship	Community people	2,025	RO	48 months
	Shushilan	Community people	1,000	PSF	11 months
	World Vision	Community people	Unknown	Unknown	48 months
Kashimari	World Vision	Unknown	Unknown	Unknown	48 months

[54] Yet unknown
[55] By the implementing NGOs

Union	Implementing agency/NGOs	Target beneficiaries	Population covered	Technology options used	Period of programme
	Shushilan	Institution	400	DTW	12 months

During 1990 – 2015 there were several water supply programmes implemented by various organizations[56] (i.e. national and international NGOs, humanitarian agencies) targeting about 195,864 community people of Dacope upazila. Reportedly, the programmes covered about 18,966 targeted households in the upazila. Through those programmes, a range of water supply technology options were implemented that include construction and repair of PSF, STW, DTW, tank for community and school, solar based PSF with piped network, RWHS at schools, RO plants.

From 2011 to till date, several water supply programmes are being implemented in Dacope upazila targeting about 36,430 community people of different spheres of which 31,830 are already covered through water supply services and facilities. Such services and facilities include construction and rehabilitation of PSF, STW, DTW, water tank for community and schools, RWHS at schools and households, and RO plants. The major implementers of the programmes are World Vision, JJS, Heed Bangladesh, Rupantar, BASD, and Care Bangladesh.

[56] Organizations include: ADO, AOSED, DPHE-GOB, GIZ, Prodipan, BASD, Christian AID, BRAC, World Vision, DSK, JJS, Heed Bangladesh, Bangladesh Red Crescent Society, USS, Bachte Shekha.

6. Gaps and Barriers Constraining Climate-Resilient Drinking Water Provision

6.1 Gaps in Geographical Coverage

The PRA process, as cited before, was used for identification of gaps in water supply in 39 Unions of 5 Upazilas under Khulna and Satkhira districts, and for mapping of functional and potential drinking water sources in the communities at household, community and institutional levels. The process involved participatory community consultation – firstly, both at Ward level (i.e. Ward PRA on water source mapping) and Union level, with knowledgeable community members (both men and women) represented by various social groups (comprising 8-10 participants in each session), e.g. Ward members, teachers, housewives, religious leaders and social workers[57]. The following tables (Table 15 and 16) presented below are based on the process outcomes showing identified gaps in drinking water supply in 39 Unions of 5 upazilas under two districts i.e., Khulna and Satkhira.

Table 15: Gap analysis of upazilas under Khulna district

Upazila	Union	No. of Ward	No. of Village	No. of HHs	HHs covered by Safe Water Options	Coverage (%)	HHs without Safe Water Options	Supply Gap (%)
Paikgacha	Deluti	9	23	4,182	544	13.01	3,638	86.99
	Lata	9	23	3,850	101	2.62	3,749	97.38
	Chandkhali	9	31	7,340	411	5.60	6,929	94.40
	Garaikhali	9	15	8,436	300	3.56	8,136	96.44
	Soladana	9	33	5,829	612	10.50	5,217	89.50
UZ Total:	**5**	45	125	29,637	1,968	6.64	27,669	93.36
Koyra	Amadi	9	30	10,410	441	4.24	9,969	95.76
	Maheswaripur	9	23	10,194	310	3.04	9,884	96.96
	Bagali	9	28	13,118	373	2.84	12,745	97.16
	Koyra Sadar	9	13	10,219	2,392	23.41	7,827	76.59
	Maharajpur	9	24	9,888	831	8.40	9,057	91.60
	Uttar Bedkashi	9	24	4,277	1,330	31.10	2,947	68.90
	Dakhin Bedkashi	9	17	5,769	2,848	49.37	2,921	50.63
UZ Total:	**7**	63	159	63,875	8,525	13.35	55,350	86.65
Dacope	Sadar	9	12	1,943	396	20.38	1,547	79.62
	Bajua	9	20	4,103	755	18.40	3,348	81.60
	Banishanta	9	15	4,102	701	17.09	3,401	82.91
	Sutarkhali	9	13	3,868	788	20.37	3,080	79.63
	Pankhali	9	11	4,400	371	8.43	4,029	91.57
	Tildanga	9	12	4,722	1,217	25.77	3,505	74.23
	Kamarkhol	9	19	3,329	813	24.42	2,516	75.58

[57] Community members and Ward members are different, while a UP Ward is a lowest tire of Bangladesh local government structure beyond Union Parishad (a Union consists of 9 Wards) and constituted by a number of communities/villages

Upazila	Union	No. of Ward	No. of Village	No. of HHs	HHs covered by Safe Water Options	Coverage (%)	HHs without Safe Water Options	Supply Gap (%)
	Laudubi	9	34	6,372	447	7.02	5,925	92.98
	Kailashganj	9	13	3,868	1,048	27.09	2,820	72.91
UZ Total:	9	81	149	36,707	6,536	17.81	30,171	82.19
Dist. Total	**21**	**189**	**433**	**130,219**	**17,029**	**13.08**	**113,190**	**86.92**

Table 16: Gap analysis of upazilas under Satkhira district

Upazila	Union	No. of Ward	No. of Village	No. of HHs	HHs covered by Safe Water Options	Coverage (%)	HHs without Safe Water Options	Supply Gap (%)
Shyamnagar	Atulia	9	34	8,621	1,865	21.63	6,756	78.37
	Ramjan Nagar	9	14	5,827	1,968	33.77	3,859	66.23
	Kashimari	9	16	7,994	5,199	65.04	2,795	34.96
	Burigoalini	9	24	6,753	1,500	22.21	5,253	77.79
	Gabura	9	17	7,486	1,983	26.49	5,503	73.51
	Kaikhali	9	18	6,409	2,328	36.32	4,081	63.68
	Padmapukur	9	12	6,316	2,371	37.54	3,945	62.46
	Munshiganj	9	19	9,315	2,868	30.79	6,447	69.21
UZ Total:	**8**	**72**	**154**	**58,721**	**20,082**	**34.20**	**38,639**	**65.80**
Assasuni	Anulia	9	24	8,380	346	4.13	8,034	95.87
	Durgapur	9	14	5,730	502	8.76	5,228	91.24
	Sreeula	9	23	7,791	1,706	21.90	6,085	78.10
	Budhata	9	24	8,955	983	10.98	7,972	89.02
	Barodal	9	23	9,028	1,371	15.19	7,657	84.81
	Khajra	9	26	7,121	404	5.67	6,717	94.33
	Kulla	9	21	7,085	1,480	20.89	5,605	79.11
	Kadakati	9	24	4,323	676	15.64	3,647	84.36
	Assasuni	9	25	6,690	2,823	42.20	3,867	57.80
	Protap Nagar	9	18	8,096	2,468	30.48	5,628	69.52
UZ Total:	**10**	**90**	**222**	**73,199**	**12,759**	**17.43**	**60,440**	**82.57**
Dist. Total:	**18**	**162**	**376**	**131,920**	**32,841**	**24.89**	**99,079**	**75.11**

6.2 Challenges in Water Supply

The coastal areas of Bangladesh are highly vulnerable to the impacts of climate change including from cyclones and tidal surges. The impacts of climate change have had a significant impact on available potable water, on both surface and groundwater in this area. The main climatic factors contributing to water scarcity in coastal areas are salinity in surface and groundwater due to sea level rise and tidal surges, and variation in precipitation pattern. Hence, consideration of possible impacts of climate change on water sources is of prime importance while selecting appropriate technologies in coastal area. In this chapter, a review of available information from secondary sources on impact of sea level rise, rainfall and natural hazards on water sources are presented.

6.2.1 Salinity in Groundwater

High salinities both in monsoon and dry season in the South-West coast and along Passur-Shibsa system of this area are associated with the decreasing upstream freshwater flow as well as siltation of the major channels[13]. According to a separate study of IWM[13], the salinity level in Rupsa river will increase due to climate change in 2050. From the model used in the study, it is evident that more salinity will intrude through Baleswar-Bishkhali river system due to climate change. This is because Passur-Shibsa system is already affected by higher salinity as there is no upstream flow for that river system during dry period (February-May). It is evident from the model that almost all the area under less than 1 ppt of salinity will be changed to more than 1 ppt by the year 2050 due to climate change[58].

The findings from a World Bank[59] study on coastal aquifers of Bangladesh suggests that the direct impacts of sea-level rise on coastal inundation and extent of storm surges is of greater concern on groundwater conditions than classical lateral intrusion. High salinity in groundwater was reported in most of the Unions during the PRA process as well. Due to this high salinity, groundwater cannot be used in most of areas. Therefore, there is a concern among local communities on availability of fresh water in this shallow aquifer in future due to salinity intrusion in this area.

6.2.2 Rainfall Pattern

The coastal region receives approximately 2,900 mm rainfall every year but more than 70% of this rainfall occurs during monsoon (June to September) every year[60] in Bangladesh. However, there is almost no rainfall for 4 to 6 months during dry season (November to March/April)[61]. Although it is predicted that rainfall levels on average could become greater, the pattern may become more irregular over coming decades[62]. This pattern of rainfall with long dry spell makes storage of rainwater for the whole year difficult as it needs a large rainwater tank to store water during the dry season.

Due to high salinity in groundwater, most families in Deluti Union depend heavily on rainwater as a source for drinking water. The local communities reported that the families get enough rainwater during the rainy period, but look for other options one or two months immediately after the rainy season. If the rainy season further shrinks in future, drinking water crisis during the dry season would exacerbate in this area.

6.2.3 Natural Hazards and Tidal Surges

Devastating cyclones hit the coastal areas of Bangladesh almost every year usually accompanied by high-speed winds, sometimes reaching 250 km/hr or more and 3-10 m high waves, causing extensive damage to life, property and livestock. Most of the damages occur in the coastal regions of Khulna, Patuakhali, Barisal, Noakhali and Chittagong and the offshore islands. The storm surges that accompany the cyclones of the Bay of Bengal cause more destruction in the coastal areas and offshore islands of Bangladesh than the very strong winds that are associated with the cyclones[63].

Cyclonic storm Aila in 2009 was one of the worst natural disaster to affect Bangladesh. Torrential rains from Aila resulted in 190 fatalities and at least 7,000 injuries across the Khulna and Satkhira Districts.

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[58] *Study report, Local level hazard maps for flood, storm surge and salinity, 2013*
[59] *World Bank, 2010*
[60] *Rahman and Akter, 2011*
[61] *Rahman and Dakua, 2012*
[62] *MoEF, 2005*
[63] *Banglapedia, 2003*

Approximately 9.3 million people were affected by the cyclone, of which 1 million were rendered homeless[64]. According to local people, the coastal embankment was badly damaged during the cyclone Aila causing intrusion of salt water into the fresh water pond in the Union. The effect of Aila and saltwater intrusion due to sea level rise on surface water sources, e.g., ponds, left a very limited number of fresh water ponds as drinking water source for people living in many villages in this Union. In absence of necessary protection measures, these sources could further be affected by tidal surges and subsurface movement of saltwater due to sea level rise.

[64] *Integrated Regional Information Networks, 2009*

7. Proposed Climate Resilient Technologies

7.1 Justification of Needs, Climate Resilience of Suggested Interventions

The primary drinking water source, throughout Bangladesh, is groundwater. Although the country has immense natural water resources, drinking water quantity and quality are greatly affected by Bangladesh's monsoonal climate (with 80% of annual rainfall occurring from June to mid-October). This seasonal nature affects the choices people make in selecting good quality drinking sources. In the dry season, rainwater is not available for drinking and surface water sources become stagnant. During extended periods, this results in local water scarcity and degraded water quality, and necessitates the use of multiple drinking water sources to meet basic personal needs (Ansari et al. 2011)

On the coast, most of the groundwater used for water supply is pumped from the top 150 m, but much of it is saline (Ravenscroft 2003; Chowdhury 2010). A study from Bangladesh Water Development Board (BWDB 2012) as shown in figure 7, indicate that groundwater salinity in the selected project areas is beyond the limit for potable and irrigation use (>2500 uS/cm). During monsoon season aquifers are expected to be flushed and recharged ringing an abundance of fresh subsurface water. However, it has been suggested that recharge owing to the presence of intermittent and thick deposits of clays remains highly variable (Ravenscroft 2003).

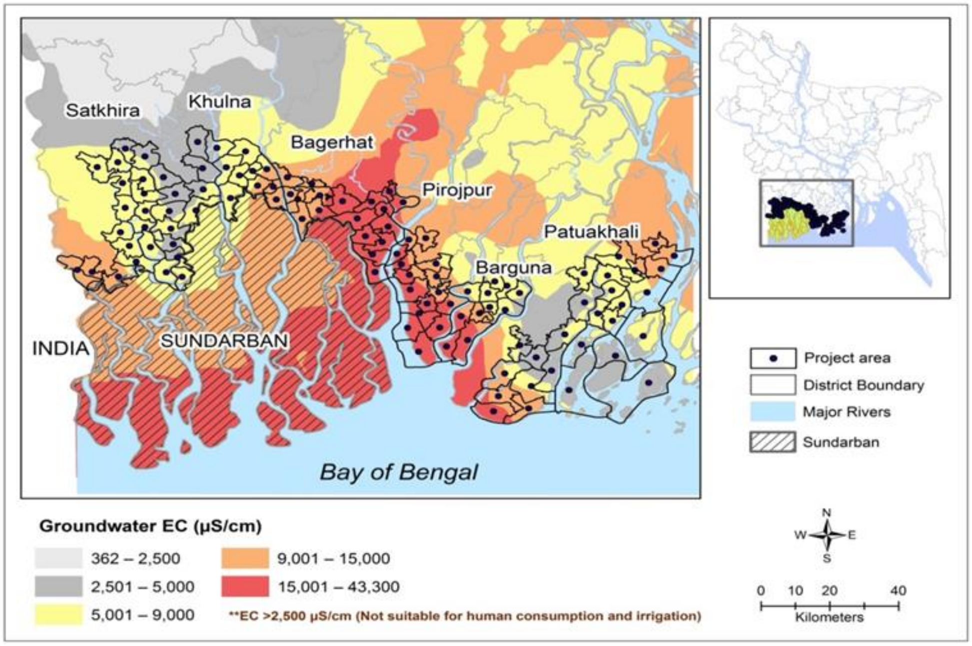


Figure 7: Groundwater Salinity in the South-west coastal zone (Data from BWDB 2012)

Apart from salinity, arsenic contamination in groundwater, is a naturally occurring phenomenon in Bangladesh. Arsenic concentration is highest in the western regions of the southwest coast, and relatively lower towards the east and most of the contaminated aquifers are within 20 – 60 m depth (NWMP, 2001). It is evident from the arsenic concentration map (figure-8) that Arsenic concentration in groundwater in the project areas in Satkhira and Khulna exceeds the Bangladesh standard of 50 µg/L

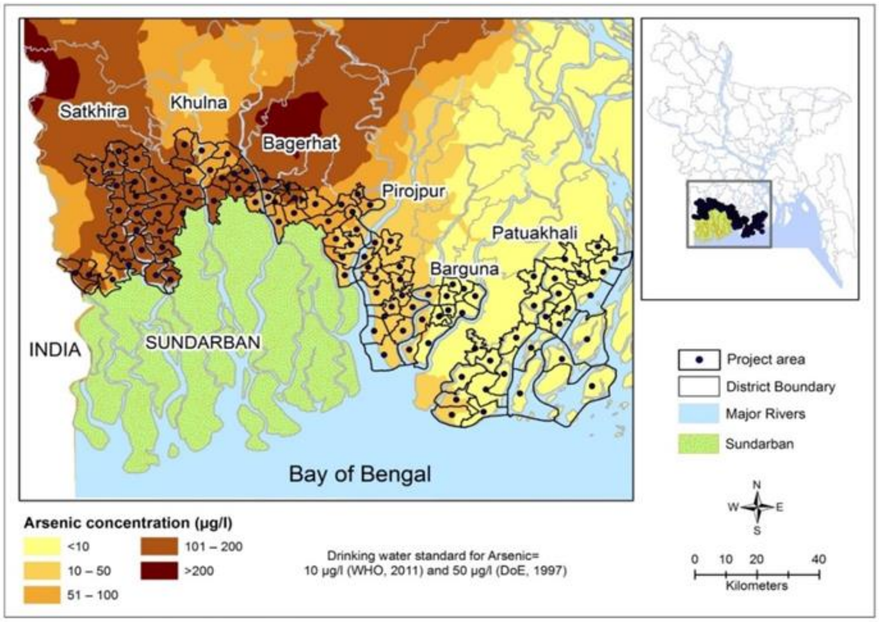


Figure 8: Southwest Coastal Bangladesh Groundwater Arsenic concentration Map (BGS Data 2001)

Due to this high level of salinity and arsenic in the water resources of in the coastal areas, the level of safe drinking water is scarce. The available water in the 5 selected upazilla is highly saline and the sources of fresh water are far away from their inhabitation and also the quality of these water sources do not comply with acceptable drinking standard.

As found from the PRA process undertaken as well as from different other secondary sources, water supply technologies[65] that currently are in use by the communities include:

1) Shallow Tubewell (STW)
2) Deep Hand Tubewell (DHTW)
3) Piped Water System (PWS)
4) Pond Sand Filter (PSF)
5) Rain Water Harvesting (RWH) System
6) Reverse Osmosis (RO) Plant, and
7) Managed Aquifer Recharge (MAR)

7.2 Options Analysis Background

The use of these technologies mostly depends on the availability of freshwater sources (surface water, groundwater and rainwater) and social acceptability of the options. However, for selection of appropriate technologies for the communities under the study districts[66] (i.e. Khulna and Satkhira), the following factors/parameters have been considered:

[65] The listed options that are currently being used by local communities are 7; while in the analyses we used 8 (eight) options (one additional) by adding 'Sky-hydrant' as a potential (improved alternative of PSF) safe drinking water option for the communities

[66] Specifically covers 39 predetermined unions only of 5 Upazilas under Khulna (3 Upazilas i.e. Paikgacha, Koyra and Dacop) and Satkhira (2 Upazilas i.e. Shyamnagar and Assasuni) district (note: these were neither covering all unions under the upazilas nor all upazilas of the districts)

- Households that are presently using the options[67]
- Availability (quantity) and quality of water
- Climate Resilience of the sources/technologies
- Ease of Operation and Maintenance (O&M): Technical aspects
- Social impact and/or acceptability
- Affordability of the users: Economic aspects
- Health impacts
- Environmental impacts

The potentials of each technology option and their applicability in the context of the study area have been assessed below against each of the above factors/parameters:

7.2.1 Shallow Tube Well (STW)

Shallow wells are normally the means of accessing ground water of shallow depths (Shallow ground water table). In this water supply system, skilled people dig into the soft ground formations (sandy to clay) until they strike the water table. A shallow well is called "unprotected" when its top is not properly covered (because dirty blown by wind or carried by surface flowing water or even the pails from the ground it rests on can enter and pollute the well. before going in the well). When fitted with a proper lid on top, it is called a protected well. In some cases, a hand-pump is also fitted to increase the protection. The Schematic diagram of Shallow Tube Well is shown in figure-9.

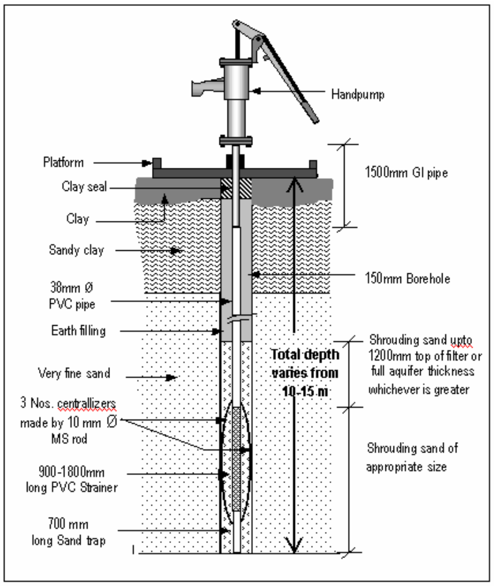


Figure 9: Schematic diagram of Shallow Tube Well

The following two technologies are often used;

- **Shallow well siting**

67 Is meant to providing 'indicative popularity' of the systems/options as sources of drinking water (except Shallow Tubewells, that are mainly being used for the domestic purposes other than drinking during normal period, while the sources are exceptionally used for drinking purpose during the period of crisis i.e. natural disasters)

A site to dig a shallow well is often identified by its hydrogeological setting; being along low-lying areas with thick soils and the type of vegetation favoring shallow water table. At times, traditional devining methods are used (eg a small branch of a special tree which breaks at the right site). In many cases, they know from history that the area has shallow-water table, and even the taste of the water (e.g. areas with or without salty water).

- **Shallow well digging**

a. **Hand Dug Shallow wells**
Normally, a hand dug shallow-well is about one to two meters (1 to 1.5yards) in diameter, depending on the size of tools used. A hand-held hoe is the commonest tool used. A small bucket, tied to a rope, is used to remove the dug soil from the hole. This process requires a team size of two or so experts. As they dig deeper, they make notches along the walls, where they step (hence a small diameter is advantageous). At times, they use locally made wooden ladders. If they reach a hard formation (eg rock) before striking the water, they abandon the well. As the depth increases, oxygen decreases in the hole. At depths of over two meters, some put fresh leaves beside the digger (although they normally may not explain the technology; the leaves actually use the carbon dioxide from the digger to produce oxygen within the hole!). While 5 meters depth, are often considered maximum, some go beyond. It takes an average of a week to finish a hand-dug shallow-well.

b. Machine dug
Some communities have appropriate technologies which assist them dig the well faster in the same soft formations. Many communities use a tripod auger (also called the Vonder Rig). It goes up to 15meters depth. Its diameter is the borehole size. This process requires an average of ten people for 2 to three days. If a mechanized drilling machine is used, a maximum of one day would be required to complete a well.

7.2.1.1 Performance and Protection of Shallow Wells

Shallow wells in clay formation are good for stability of their walls, but recharge is usually slow if many people draw water from it. The result is a common long queue of people awaiting water recharge in the well. On the other hand, shallow-wells in sandy formations tend to be hazardous as they collapse easily, but their recharge is usually fast due to much higher porosity compared to the clay formations. This problem is usually managed by lining the well's walls with locally made materials such as bricks or baskets. A concrete slab is often put on top to prevent pollution. Where resources allow, a pulley system or better still, a hand-pump is installed to lift the water to the surface.

7.2.1.2 Feasibility of STW

Factors Considered	Analysis	Proposition
User households/ Population (average 5.368 persons per HH in total)	In Khulna and Satkhira 6,355 HH are using water from 593 STW (2.4% of total), out of which 2,349 HHs have own STWs. (In addition 339 STW identified as potential). **Note:** shallow tubewells are mainly being used for the domestic purposes other than drinking during normal	STWs are not recognised as safe sources of drinking water and hence not

[68] There are 262,139 households and 1,378,859 population (including male and female) counted in total in the study areas through the PRA process

Factors Considered	Analysis	Proposition
	period, while the sources are exceptionally used for the drinking purpose during the period of crisis i.e. natural disasters.	included as improved water source for this study. DPHE-GOB also doesn't promote STWs in its implementation program. In the context of the study area, these are not also safe sources for drinking purpose. During the PRA process undertaken, the community people didn't propose STWs. Hence, STW is not considered as proposed technology option for the study area.
Availability/quantity and quality of water sources	The shallow groundwater layer is available in some unions of the study area but except some pocket area there is high concentration of arsenic, iron and chloride in this layer. The layer is not available for extraction of water round the year as well due to dry-season depletion.	
Climate Resilience	The shallow groundwater source is mostly arsenic contaminated and vulnerable to salinity intrusion and thus STW water is not suitable for drinking. During dry season, many STWs become non-functional due to depletion of water table and during disaster many STWs are inundated under salt water and become unusable, if platforms are not raised above flood level.	
Ease of Operation and Maintenance (O&M): Technical	The STW are operated by using No.6 hand pump which operates on suction mode. The operation and maintenance of this hand pump is simple, user-friendly and can be easily maintained by the households.	
Social impact and acceptability	Where Shallow layer is available, the people install STW adjacent to their houses and they use this STW water for all domestic purposes which they perceive suitable for drinking rather than drinking pond water in case there are no other safe sources nearby.	
Affordability of the users: Economic aspects	The cost of a STW ranges from BDT 8,000- 10,000, which poor people cannot afford. The water is free, repair and maintenance cost is very insignificant.	
Health impacts	Except few STWs in safe pocket sources, the water of most of the STWs is not safe for personal, public and reproductive health (i.e. drinking and people drinking STW water are exposed to high risk of poisonous effect of arsenic and other intestinal diseases).	
Environmental impacts	There is no visible adverse effect of STW water on the environment. However, The STW installed nearby latrine are likely to be polluted by the short-circuiting of faecal mobility especially during disaster or heavy rainfall.	

7.2.2 Deep Hand Tube Well (DHTW)

High salinities both in monsoon and dry season in the South-West coast and along Passur-Shibsa system of this area are associated with the decreasing upstream freshwater flow as well as siltation of the major channels (BWDB, 2013). According to a study of World Bank (2010) study on coastal aquifers of Bangladesh, the direct impacts of sea-level rise on coastal inundation and extent of storm surges is of greater concern on groundwater conditions than classical lateral intrusion. During the study, groundwater in a number of Unions was not found suitable for drinking purposes due to high salinity concentration. Moreover, the tendency of salinity intrusion in this region indicates that the aquifers could be affected by salinity in future as climate change risks evolve. However, in few Unions fresh water aquifers were available and people were found collecting drinking water from these sources. As groundwater is not affected by salinity, deep tube wells were considered as a potential option for those Unions.

Deep tube wells, where applicable, would also be a popular option as the system is user friendly and needs very low maintenance. Due to its low maintenance cost, water from this system would be affordable to the local communities too.

7.2.2.1 Feasibility of DHTW

<table>
<tr><th>Factors Considered</th><th>Analysis</th><th>Proposition</th></tr>
<tr><td>User households/ Population (average 5.3 persons per HH in total)</td><td>2,586 DHTWs in total are being used by 22,522 households (8.6% of total). Out of this total 861 HHs have individual options (rest 21,661 households use either community or institution based options) of which 518 are found functional and 343 are identified as potential options/sources</td><td rowspan="5">DTWs are recognised as safe sources of drinking water and hence included as improved water source in JMP. DPHE solely depend on DTWs for increasing safe water coverage in the study area where safe deep layer is available. In the context of the study area, these are also considered as safe sources for drinking. During the PRA session, the community people clearly proposed for DTWs. Hence, DTW has been considered as proposed technological option for the study area.</td></tr>
<tr><td>Availability/quantity and quality of water sources</td><td>The deep groundwater layer is rarely available in most of the unions of the study area and hence DTW is not feasible in many unions. During the study, groundwater in a number of Unions was not found suitable for drinking purposes due to high salinity concentration. However, in a few Unions freshwater aquifers were available and people were found collecting drinking water from these sources.</td></tr>
<tr><td>Climate Resilience</td><td>According to a study of World Bank (2010) on coastal aquifers of Bangladesh, the direct impacts of sea-level rise on coastal inundation and extent of storm surges is of greater concern on groundwater conditions than classical lateral intrusion. Moreover, the tendency of salinity intrusion in this region indicates that the aquifers could be affected by salinity in future as climate change risks evolve. However, it was learnt from PRA session that most of the existing DTWs are functioning well and discharging safe drinking water.</td></tr>
<tr><td>Ease of Operation and Maintenance (O&M): Technical</td><td>The DTW are operated by using No.6 hand pump which operates on suction mode. The operation and maintenance of this hand pump is simple, user-friendly and can be easily maintained by the households.</td></tr>
<tr><td>Social impact and acceptability</td><td>DTW is the most popular and socially acceptable option due to extraction of safe drinking water, where safe groundwater layer is available. The year round availability of safe free water and minimum maintenance make the option more attractive to the people. This is why, the people in the places where no tubewell is available collecting DTW water from distant places directly or through van drivers even with transportation cost.</td></tr>
</table>

Factors Considered	Analysis	Proposition
Affordability of the users: Economic aspects	Most of the DTWs are public and are installed by either DPHE or NGOs with minimum 10% contribution from the user households. The contribution amount ranges from BDT 6000- 7500, which is shared by 5-10 households, which is affordable by the poor households. The DTW water is free and repair and maintenance cost is very insignificant (i.e. affordable for all community segments)	
Health impacts	The DTW water is arsenic and bacteriologically safe for drinking and there is no adverse health effect. DTW water also usually contains mineral items within acceptable range, which reduces mineral deficiency of the health.	
Environmental impacts	There is no adverse effect of DTW water on the environment.	

7.2.3 Piped Water Supply (PWS)

7.2.3.1 Feasibility of PWS

Factors Considered	Analysis	Proposition
User households/ Population (average 5.3 persons per HH in total)	3,896 households in total are using drinking water from 614 community based PWS (1.5% of total).	Due to unknown household cluster setting, topography of the area and depth of suitable aquifer, the capital cost of a piped water system cannot be estimated. Again, the community based viable institutional arrangement has not been experienced in the study areas. This is why community based piped water supply system has not been proposed. Instead, DTWs have been
Availability/quantity and quality of water sources	The deep groundwater layer is rarely available in most of the unions of the study area and hence groundwater based PWS is not feasible in many unions. However, in a few Unions piped water supply installed by GIZ is available and people were found collecting drinking water from specific stand points nearby household clusters. These piped water systems either use groundwater source or pond water nearby.	
Climate Resilience	The piped water system is normally resilient to disaster shocks and can continue water supply, if pond water source is not polluted by salt water intrusion.	
Ease of Operation and Maintenance (O&M): Technical	The piped water system is required to be operated by a trained pump operator and the supply lines need to be continuously checked for leakage and uninterrupted water supply. The system is operated by either electricity or solar energy. A strong institutional arrangement is required for sustainable operation of PWS, which was found absent in most of the existing PWS in the study areas. The O&M cost is required to be recovered from the users through tariff.	
Social impact and acceptability	Piped water supply is a desired option in the study area due to its ability to supply water at the door step of the households requiring zero or minimum collection effort especially by women.	

Factors Considered	Analysis	Proposition
Affordability of the users: Economic aspects	Due to unknown household cluster setting, topography and depth of suitable aquifer, the capital cost of a piped water system cannot be estimated. However, the community has to contribute up to 10% of the capital cost to get connected into the PWS. Besides, the user households have to pay monthly tariff at the rate of BDT 150-200, which is affordable by the users in consideration of potential benefits of PWS in terms of easy access to the PWS and convenience of water collection without any cost and effort.	proposed to cover dispersed household setting in the villages where fresh deep aquifer is available.
Health impacts	The PWS water is arsenic and bacteriologically safe for drinking, if not polluted through piped system.	
Environmental impacts	There is no adverse effect of PWS water on the environment.	

7.2.4 Rainwater Harvesting System (RWHS)

The coastal region of Bangladesh receives approximately 2,900 mm rainfall every year but more than 70% of this rainfall occurs during monsoon (Rahman and Akhter, 2011). This huge amount of rainfall every year makes rainwater harvesting a potential solution to fulfil the water demand in this region.

Rainwater harvesting (RWH) is a widely used term covering all those techniques whereby rain is intercepted and used 'close' to where it first reaches the earth. RWH can be considered as a probable solution of drinking water crisis in areas where there is no possibility of providing safe water cheaply within a reasonable distance of homes, because the ground conditions are unsuitable and surface waters are polluted or absent. For example, the ground may be impermeable (rock/stony layers precluding tubewell construction), groundwater may be over-mineralized by fluorides, iron or even heavy metals (e.g. Arsenic contamination in Bangladesh), or the aquifer may have saline zones such as in the coastal areas, the aquifer may be too deep to reach or groundwater table rapidly declining. In these situations the harvested rainwater can be a valuable alternate water supply option. The rainwater is free from arsenic and other impurities. The physical, chemical and bacteriological characteristics of harvested rainwater usually represent a suitable and acceptable standard of potable water.

7.2.4.1 Elements of a Rainwater Harvesting System

The fundamental elements of a rainwater harvesting system include:

- **Collection/Catchment Surface:** The collection surface from where the rainfall runs off.
- **Conveyance:** Roof runoff is typically conveyed to a rainwater collection system via gutters with downspouts or roof area drains with leaders. Filtration devices are often used to remove particulate contaminants en-route to storage. In some systems, a first-flush method is used to completely bypass an initial amount of roof runoff so that it cannot enter storage.
- **Storage:** Tanks or cisterns are used to store harvested rainwater which may be placed in various locations. A number of processes automatically occur within the tank itself such as settlement, flotation and pathogen die-off. Finally, some technique of disinfection (such as chlorination, solar

disinfection or use of a ceramic filter) may be employed to the water after it is drawn from the tank.

- **Distribution/delivery system:** Using harvested rainwater to fulfil designated uses in normally requires filtering, treating, controlling flow to end use, monitoring storage tank levels, and/or controlling the need for switching to backup/bypass/makeup water.

7.2.4.2 Collection/ Catchment Surface

A catchment is an extent of exposed surface area on which precipitation falls and flows towards a draining point. The volume and rate of rainwater runoff are functions of catchment area, intensity and duration of rainfall, slope of the surface, and type of surface material. Roofs are considered as the first and most effective choice for catchments.

Water quality from different roof catchments is a function of the type of roof material, climatic conditions, and the surrounding environment. Thin metal sheets (Galvanized iron, mild steel etc.), often corrugated, are the most commonly used roofing material in rural areas. Because of the smooth texture, the rainwater collection is very efficient. Some caution must be exercised regarding roofing surface paints. Asbestos sheeting or lead-painted surfaces should be avoided by all means. Rainwater collected from roofs with copper flashings may cause discoloration of porcelain fixtures. Roofs made of clay or concrete tiles deliver rainwater which are suitable for both potable and non-potable use, but may contribute as much as a 10 percent loss due to rough texture, obstacles in flow, evaporation and porosity. Bacterial growth is encouraged in rough surfaces and dirt may be accumulated on the corner of the tiles. To reduce water loss and prevent growth of microorganisms, tiles are painted or coated with a sealant. In this case, special sealants should be used containing little or no toxic materials. Roofing materials made of asphalt shingles (tar-like hydrocarbon speckled with colored small ceramic granules) are prone to leaching of toxins from colored shingles and the harvested water may not be appropriate for direct consumption as potable water.

7.2.4.3 Rainwater Conveyance

Rainwater is typically conveyed from the collection surface (roof) to a storage tank or cistern in two ways:

1. A sloped roof typically drains to gutters and downspouts at the outer edges(s) of the structure. Scuppers, oversized gutters, and other methods are employed for overflow protection.
2. A flat or semi-flat roof may use roof area drains that connect to leaders (downspouts/ rainwater downpipes). Particularly for horizontal surfaces there shall be parapet around the surface to prevent free-fall of rainwater.

7.2.4.4 Rainwater Storage

While the tank is the largest component of storage, there are numerous supporting components that are fundamental to the functioning of this element. The components of a storage system include the following (figure 10): (1) Tank, (2) Rainwater Inlet from Conveyance (may enter the tank from top, side), (3) Calming Inlet (minimizes disturbance of sediment at bottom of tank by reducing agitation from the incoming water), (4) Intake (provides extraction of water from a location below top surface. Generally, higher water quality is found below the top surface and above the very bottom of the tank. (5) Overflow (excess water flows out of tank to grade, stormwater sewer, stormwater control devices, or other appropriate path as per local requirements (6) Vent (provides ventilation for stored water and pressure relief from incoming water) (9) Tank Access (should be secured to prevent unauthorized access).

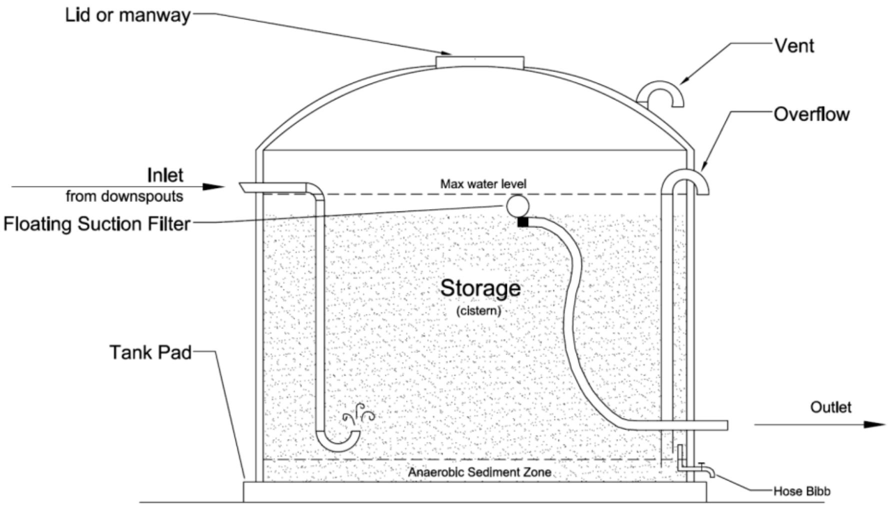


Figure 10: Different components of a rainfall cistern

7.2.4.5 Rainwater Distribution System

Distribution system is the element responsible for delivering water with the appropriate quality and pressure. All the components in distribution system must be chosen carefully for compatibility and application. Distribution is affected by factors such as location of the tank and the water supply expected from the rainwater system. In the rural context, at the household level water can be collected and used from the storage tank directly which may undergo a certain form of treatment/ disinfection (UV, chlorination, etc.) in a separate container.

7.2.4.6 Water Quality Management in RWHS

The potential of water quality contamination throughout a rainwater harvesting system necessitates the use of intervention options to produce water of suitable quality for potable and non-potable uses. Potential intervention options for rainwater collection systems include improved design features (positioning of inlet, altering the location of collection systems), pre-storage measures (debris screens and filters and first-flush diversion), and post-storage measures (post-storage filtration and disinfection).

7.2.4.7 Tank Maintenance

The success and overall usefulness of a RWH system will be largely determined by how a system is maintained. Downspout filters should be installed at a location easily seen and accessed by system users to facilitate frequent inspection and cleaning. Pump filters and treatment filters should be easily accessed and cleaned as well. Storage tanks should have access ways and drawdown valves should be installed to make tank cleaning and sediment removal easier.

7.2.4.8 Feasibility of RWHS

Factors Considered	Analysis	Proposition
User households/ Population (average 5.3 persons per HH in total)	5,659 HHs are using water from RWHS (2.2% of total)), out of which 4,746 HHs have their own systems (only 26 HH based RWH identified as potential, while rest others are found presently functional).	Due to abundance of rain water in the study area along with people's traditional practice, familiarity with and fascination for the RWH, this option has been proposed as the main technological options in the study area. During the PRA session, the community people expressed their high desire for RWH.
Availability/quantity and quality of water sources	The coastal region receives approximately 2,900 mm rainfall every year but more than 70% of this rainfall occurs during monsoon (June to September) every year (Rahman and Akhter, 2011) in Bangladesh. This huge amount of rainfall every year makes rainwater harvesting a potential solution to fulfil the water demand in this region. Despite rainwater being not available for 4 to 6 months of the year, people in most of the Unions were found heavily dependent on rainwater for drinking purpose. During the PRA, local communities reported that households get enough rainwater during rainy period, but have to look for other options one or two months immediately after the rainy season as they cannot store enough rainwater to fulfil their demand for whole dry season. Therefore, rainwater harvesting system with adequate storage capacity to store rainwater for whole dry season, which also needs to be designed considering the rainfall pattern in this area, could be a good solution for people in this region. + RWH can reduce exposure to waterborne pathogens by providing improved potable water quality and water for other household purposes, including hygiene, bathing and washing69.	
Climate Resilience	Future changes in rainfall patterns need to be considered when deciding the size of storage, given that there is almost no rainfall for 4 to 6 months during dry season (Rahman and Dakua, 2012). Although it is predicted that rainfall levels on average could become greater, the pattern may become more irregular over coming decades (MoEF, 2015). This pattern of rainfall with long dry spell makes storage of rainwater for the whole year difficult as it needs a large rainwater tank to store water during the dry season. During disaster (cyclone), the roof of the user household being used as catchment area is likely to be damaged. However, the rainwater tank constructed on a raised platform remains intact and provides store of safe drinking water.	
Ease of Operation and Maintenance (O&M): Technical	The system is based on low operation and maintenance requirements: mostly simple cleaning and basic repairs.	

[69] UNICEF 2014

Factors Considered	Analysis	Proposition
	Where not normally practised, local manufacture and supply of materials may be weak or non-existent.	
Social impact and acceptability	Widespread practice, relatively low-tech and low-cost: stored rainwater is a convenient, inexpensive water supply close to home – which can decrease the time spent fetching water or queuing at water points. It generally requires little training or capacity building, only local supply chains for storage containers and system components should be in place.	
Affordability of the users: Economic aspects	The cost of the RWH system with 2000 litre plastic water tank ranges from BDT 20,000 to 25,000, which is not affordable by the poor people. But people are mostly interested to get RWH from DPHE or NGO with cost contribution of 10%. The rainwater is free and repair and maintenance cost is very insignificant. The costs of high quality storage containers may still be a major investment for poor rural households. Group investments can help.	
Health impacts	The RWH water is fresh water and is bacteriologically safe for drinking if the catchment, gutter system and water tank are cleaned regularly and hygienically maintained. However, water quality deteriorates after one or two month of the rain, if not preserved properly.	
Environmental impacts	There is no adverse effect of RWH water on the environment.	

7.2.5 Pond Sand Filter (PSF)

PSF is an alternative and popular option of potable water supply in coastal belt and arsenic prone areas. PSF is a simple low-cost technology with very high efficiency in turbidity and bacterial removal constructed with locally available materials and trained masons. It is a type of slow sand filter unit developed to treat surface water, usually pond water for domestic water supply. Slow sand filter is installed near or on the bank of pond, which does not dry up in the dry season. The water from the pond is pumped by a manually operated hand tube well to feed the filter bed, which is raised from ground, and the treated water is collected through tap(s). It has been tested and found that the treated water from a PSF is usually bacteriologically safe or within tolerable limits.

7.2.5.1 Site Selection for PSF

PSF is usually constructed in areas where DHTW are not feasible for installation due to hard layer or non-availability of suitable aquifer producing acceptable quality and quantity of water. Moreover, areas where the shallow aquifer is contaminated with arsenic or existence of excessive salinity in the ground water, PSF can be used as the alternative solution. Since this technology is highly dependable on filtering surface water, special emphasis should be given on selecting ponds for this technology.

- The pond should be large enough and water should be available throughout the year.
- The pond should not be used for washing and bathing purposes.

- The pond should not be used for pisiculture and in no way any fertilizer or any chemical will be used in pond water for any purpose. But natural fish can grow by itself without any external influence/support.
- The pond dike needs to be repaired as & when required, particularly before rainy season to protect agricultural, domestic and other waste runoff into the pond.
- The pond should be at a safe distance from latrines and cowsheds. Duck or any kind of poultry rearing in hanging shed over the pond must be prohibited.
- The salinity of the water should not exceed 600 ppm at any time of the year.

7.2.5.2 Water Quality Maintenance of PSF

PSF perform best under continuous operation and constant flow conditions. A 24-hour operation makes maximum use of the plant. Traditionally PSF connects with fresh water pond to supply raw water. In present coastal context, fresh water pond is not available and maximum existing pond water are saline. Existing fresh water ponds are re-excavated with proper bank management to protect from tidal surge and flood. These ponds mostly rainwater fed pond and soil protection can be done to protect leaching by using clay or other materials. New excavated pond is kept for one year after excavation for filling rainwater than PSF are constructed for supplying safe water.

7.2.5.3 Feasibility of PSF

Factors Considered	Analysis	Proposition
User households/ Population (average 5.3 persons per HH in total)	A total of 617 PSFs are found installed, out of which 309 are presently functional and being used by 14,926 HHs (5.7% of total).	Due to maintenance difficulties, PSFs have not been proposed for safe drinking water coverage. Instead, Sky hydrant technology has been proposed, which are more sustainable and requires minimum maintenance, which can be taken care of by a skilled operator. The cost of water supply is also very minimum and affordable by the users. During the PRA session, the community people proposed installation of some PSFs where fresh ponds are available. However, These proposed PSFs have been replaced by sky-hydrants.
Availability/quantity and quality of water sources	PSF is an alternative and popular option of potable water supply in coastal problematic areas, where DTWs are not feasible. There are a number of fresh ponds either private or public in almost all unions of the study area. PSFs are based on these fresh ponds and filter pond water to remove turbidity and all other impurities including harmful bacteria. One PSF can adequately provide water to 30-50 households located nearby the ponds.	
Climate Resilience	Due to intrusion of salt water during tidal surges, especially during Aila in 2009, many fresh water ponds were damaged and have become saline. However, few fresh water ponds survived from saltwater intrusion and are currently being used during dry seasons by local people. However, these ponds are always exposed to risk of salt water intrusion during cyclone and tidal surge and PSFs based on these ponds are also at risk of being non-functional due to increased salinity of the pond water.	
Ease of Operation and Maintenance (O&M): Technical	These ponds are not often perennial and dry up during 4 months dry season when operation of PSFs become difficult due to inadequate water availability and high concentration of salinity in the pond water. But it was observed that due to operational and maintenance difficulties (cleaning of filter beds, manual lifting of water into the filter chambers, lack of repair/maintenance funds, etc.) these PSFs cease to operate and are often abandoned.	
Social impact and acceptability	PSFs are also popular options and are socially acceptable community options. These are preferred next after RWH and are used as conjunctive or supplementary source of safe drinking water when harvested rainwater stock diminishes.	
Affordability of the users: Economic aspects	The cost of a PSF ranges from BDT 50,000- 70,000 depending on the size of the chambers. The pond preservation and raising of embankment are necessary requirement of a PSF, which also increases cost and the users have to contribute at least 10% capital cost of PSF. Again the filter media is required to be cleaned after every three months and replaced as and when needed, which requires a significant costs and user are often reluctant to pay that cost. The PSF water is free.	
Health impacts	The PSF water is bacteriologically safe for drinking, if PSFs are properly maintained.	

Environmental impacts	There is no adverse effect of PSF on the environment.	

7.2.6 Sky-hydrant

Sky-hydrant is a membrane filtration unit which filters raw water and make the output 100% free from coliform/bacteria, and turbidity. It has a filtration unit through which raw water passes by gravity force and produces fresh water at the output. Preferable source of raw water could be sweet surface water from pond, river, lake, etc. The Sky Hydrant water purification unit produces safe drinking water without the need for power or chemicals. It is a low cost, lightweight (16 kg) portable and easy to deploy in the field. The UF membrane is robust, cleanable and has a service life of 10 years. Operating functions are simple and manual, with virtually no consumables. These units are designed to produce water for 500-1000 people as standalone unit, or can be configured for larger capacity. A single unit can produce up to 1000 litres per hour. The Schematic diagram of Sky-hydrant system is shown in figure-11.

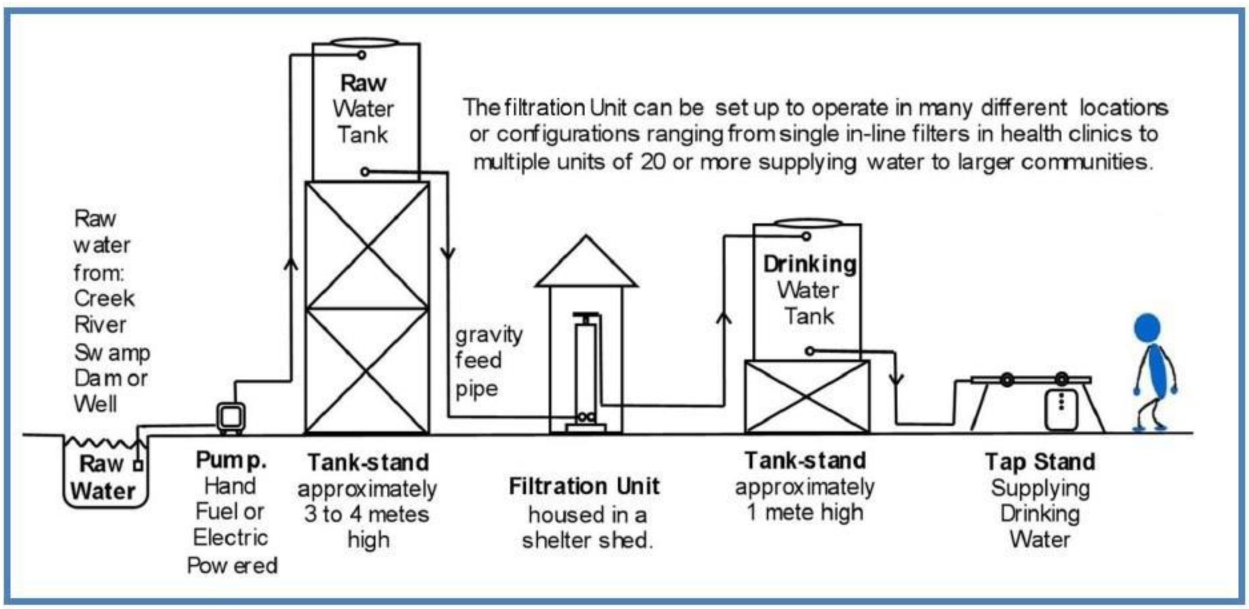


Figure 11: Schematic diagram of Sky-hydrant system

7.2.6.1 Water Quality Maintenance of Sky-Hydrant

Not all water is suitable for filtering through the sky hydrant ultra-filtration unit. The sky-hydrant will remove biological contaminates and pathogens including bacteria, viruses, protozoa etc. making water safe to drink. The sky hydrant will remove turbidity and dirt from water. Dirty water can however damage the filter fibres and it is recommended to install a pre-filtration system. However, the sky hydrant will not remove salt, dissolved chemicals and minerals from water.

7.2.6.2 Feasibility of Sky-hydrant

Factors Considered	Analysis	Proposition
User households/ Population (average 5.3 persons per HH in total)	New system (none found in the study area) is being implemented by GOB-led HYSAWA project in Satkhira district (but in the areas out of study)	Due to simple and low cost of maintenance, and sustainable operation, Sky-hydrants are becoming popular in the coastal areas and are replacing PSFs. Hence, Sky-hydrants have been proposed as improved alternative technologies of PSFs in the study area.
Availability/quantity and quality of water sources	Sky-hydrant is a membrane filtration unit which filters raw water and make the output 100% free from coliform/bacteria, and turbidity. It has a filtration unit through which raw water passes by gravity force and produces fresh water as output. All fresh ponds, rivers and lakes are the preferred source of water for sky-hydrant.	
Climate Resilience	The sky-hydrant modules are installed in a well-protected superstructure, which are resilient to disaster shocks. In some areas of the coastal region, Sky-hydrants have been used for 3 years. However, protection of these ponds from tidal surges during cyclones will remain a challenge in this area	
Ease of Operation and Maintenance (O&M): Technical	This system is operated by electricity or by solar energy and can be easily maintained by a trained caretaker. The sustainable O&M requires some institutional arrangement to recover O&M cost through tariff.	
Social impact and acceptability	This is a new water technology, but in use for last 3 years in the coastal areas. Although many coastal people are not familiar with this technology, but this is a well-accepted technology due to its smooth functioning, minimum maintenance and wide coverage.	
Affordability of the users: Economic aspects	The cost of a Sky-hydrant is around BDT 1,000,000 including cost of superstructure. The users have to contribute at least 10% capital cost of Sky-hydrant, which is shared by 150-200 households. The Sky-hydrant water is not free. The tariff has been estimated at BDT 100 per month for collection of 30 liter water per day (2 Pitcher). The tariff has also been fixed on piecemeal basis i.e. BDT 2.00 per pitcher as evidenced in HYSAWA area, which is affordable by the users.	
Health impacts	The Sky-hydrant water is bacteriologically safe for drinking.	
Environmental impacts	There is no adverse effect of Sky-hydrant on the environment.	

7.2.7 Managed Aquifer Recharge (MAR)

Managed Aquifer Recharge (MAR) was found to be used as a source of drinking water in few Unions where Department of Public Health Engineering (DPHE) installed these systems under an action research which is still going on. In this technology, water is collected from ponds and roofs and, after passing through a sand filter, is then injected into the shallow saline aquifer through a ring of infiltration wells, creating a lens of fresh water. After the turbidity of the infiltrated water has improved to an acceptable level, water can be abstracted using a standard hand pump yielding water of improved quality (reduced levels of turbidity, coliforms, iron and arsenic). This system remains operational during rainy season only, when rainwater is abundant.

Importantly for Bangladesh, storage of fresh water in the ground offers significant flood protection during the regular cyclonic surges and MAR system provides safe water when other traditional sources have been damaged by the floods.

Though MAR is increasingly being considered as a good option for water supply in few countries as it provides large storage capacity to capture intermittently available excess seasonal water for use during dry season, the system is yet to prove its effectiveness in the context of salinity affected coastal districts. The major challenge for the MAR system in coastal areas is proving its technological sustainability and solving maintenance issues. Its potential for scaling up in coastal region would largely depend on its performance, and identifying the specific conditions (e.g., salinity level, catchment characteristics, depth of water table, etc.) where MAR would be beneficial. The action research on application of MAR with options to store pond water and rainwater into shallow, brackish aquifers in 20 sites on the coastal plains of Bangladesh through recharge well under gravity is currently being conducted in coastal areas of Satkhira, Khulna and Bagerhat (Sultana and Ahmed, 2014). The Schematic diagram of Managed Aquifer Recharge is shown in figure-12.

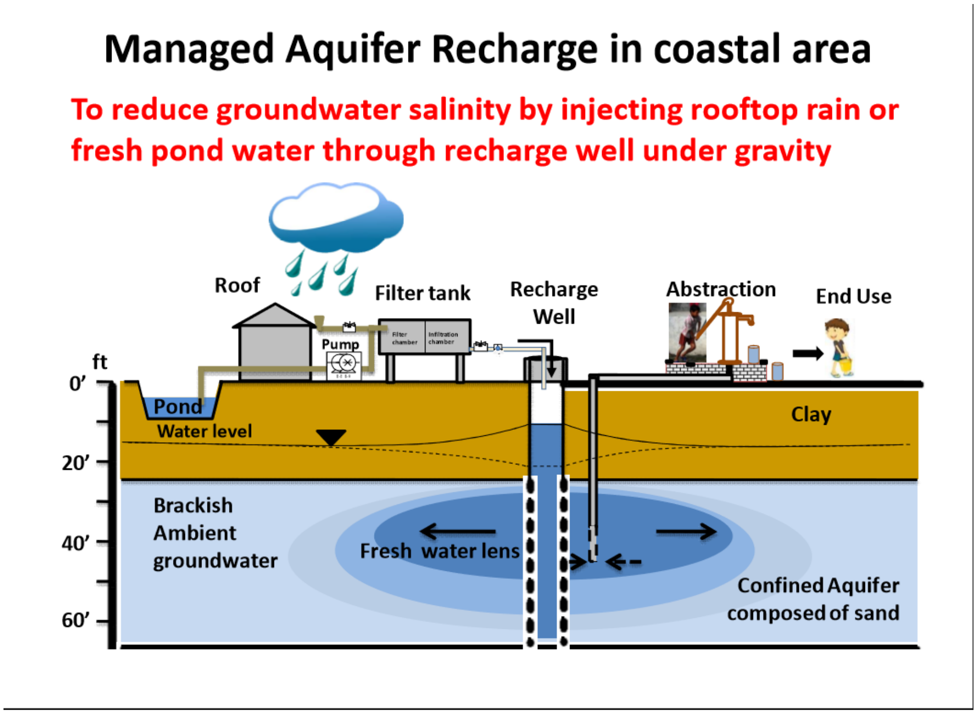


Figure 12: Schematic diagram of Managed Aquifer Recharge

7.2.7.1 Feasibility of MAR

Factors Considered	Analysis	Proposition
User households/ Population (average 5.3 persons per HH in total)	Total 370 HHs (0.01% of total) are using 5 MAR. (1 MAR identified as potential)	Since potential of MAR and its applicability in salinity affected coastal region is yet to be proven, it was not considered as proposed technology option for the study area.
Availability/quantity and quality of water sources	Managed Aquifer Recharge (MAR) was found to be used as a source of drinking water in few Unions where Department of Public Health Engineering (DPHE) installed these systems under an action research which is still going on. This system remains operational during rainy season only, when rainwater is abundant. The system uses pond water, which is stored rainwater and have been used for drinking and cooking by the families living around the pond.	
Climate Resilience	The MAR system is yet to prove its effectiveness in the context of salinity affected coastal districts. From the results of the research currently being conducted in 20 sites in coastal districts, it appears that the major challenge for the MAR system in coastal areas is proving its technological sustainability and solving maintenance issues. Its potential for scaling up in coastal region would largely depend on its performance, and identifying the specific conditions (e.g., salinity level, catchment characteristics, depth of water table, etc.) of the areas to be considered for MAR implementation. The risk of salt water intrusion into the pond during disaster is a potential threat for MAR operation.	
Ease of Operation and Maintenance (O&M): Technical	The system is under action research in few coastal unions, results of which is yet to be captured/learnt and disseminated.	
Social impact and acceptability	Comparatively a new technology in the study area and is yet to prove its social acceptability; however hypothesis70 used behind the technology suggest that stored runoff can be used for non-potable uses (e.g. garden irrigation), reducing pressure on higher quality (domestic) sources. In some regions stored water can be used for drinking in the dry season with adequate treatment. Storage provides a good alternative when water availability is insufficient, but technical, environmental, social or legal concerns may preclude development of reservoirs if they are too large.	
Affordability of the users: Economic aspects	Under action research. O&M cost has not been estimated; however it requires potentially high costs depending on the scale of the project and location (availability of donors may help, but issues of sustainability when project completed).	
Health impacts	The MAR water is believed to be bacteriologically safe for drinking.	

[70] UNICEF 2014

Factors Considered	Analysis	Proposition
Environmental impacts	There is no proven adverse effect yet of MAR on the environment. However, capturing runoff can affect downstream communities, reducing their water availability. Additionally, directing excess runoff down, for example, abandoned wells to recharge aquifers can fast-track contamination.	

7.2.8 Reverse Osmosis (RO) Plant

The RO system is based on a desalination process and can use both surface (i.e. river) water and groundwater irrespective of salinity and other contaminants to produce safe drinking water. This makes this technology option resilient to increasing levels of salinity in the coastal areas of Bangladesh. In this process water is made to pass from the more concentrated solution to a less concentrated one which is the principle of process of osmosis. The force necessary to accomplish this is the application of pressure greater than the osmotic pressure of the saline solution. When saline solution is in contact with semi permeable membrane which is placed under pressure being in excess of its osmotic pressure, water from the solution will flow through the membrane. Water flow will continue till the pressure created by the osmotic head equals the osmotic pressure of the salt solution.

Reverse osmosis treatment reduces the concentration of dissolved solids, including a variety of ions and metals and very fine suspended particles such as asbestos that may be found in water. RO also removes certain organic contaminants, some detergents, and specific pesticides. Although RO membranes can remove virtually all microorganisms, it is currently recommended that only microbiologically safe (i.e., coliform negative) water be fed into RO systems.

Acetate membranes have proved most successful to be used for this purpose. The salt content in the water produced can be controlled by reducing the pressure or increasing the number of filtrations. The Schematic diagram of Reverse Osmosis system is shown in figure-13.

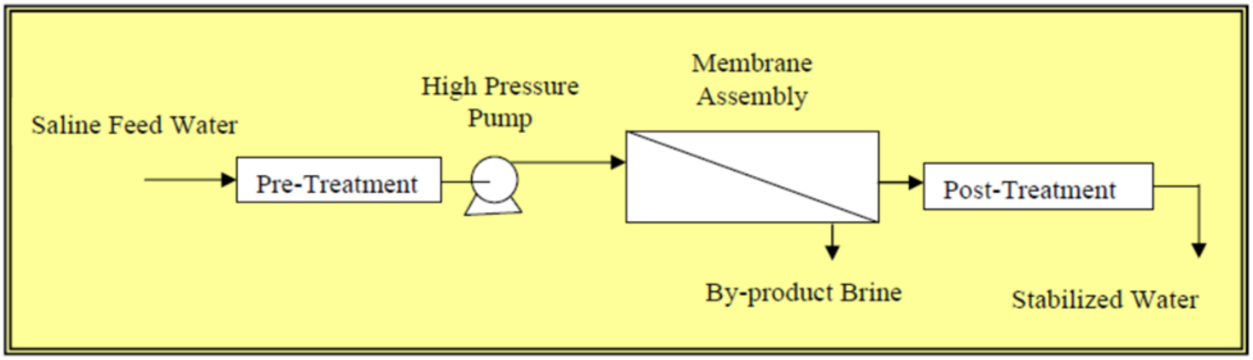


Figure 13: Schematic diagram of Reverse Osmosis system

7.2.8.1 Characteristics of RO Plant

The main attraction of this process is its low energy consumption. The energy required for operating the process increases with feed water salinity. RO process is suitable for both sea and brackish water. There are flexibility in water quantity and quality. This process requires low power consumption compared to other desalination plant. On the other hand, this process requires high quality feed water. The operational and maintenance cost is relatively higher than other desalination plant. This technology also requires higher pressure for functioning.

7.2.8.2 Maintenance of RO system

An RO system must be well maintained to ensure reliable performance. Clogged RO membranes, filters, or flow controls will decrease water flow and the system's performance. If fouling is detected in the early stages the membrane can often be cleaned and regenerated. The cleaning procedure varies depending on the type of membrane and fouling. Completely clogged or torn RO membranes must be replaced. In addition, pre- or post-filters must be replaced once a year or more often, depending on the volume of water fed through the system and the quality of the feed water. Damage to RO membranes cannot be seen easily. The treated water must be analyzed periodically to determine whether the membrane is intact and doing its job. Many systems now have a built-in continuous monitor that indicates a high TDS level, a sign that the system is not operating properly. It may also be necessary to test regularly for specific health-related contaminants such as nitrates or lead. Microorganisms, dead or alive, can clog RO membranes. To prevent bio-fouling, RO units must be disinfected periodically with chlorine or other biocides provided by the manufacturer. Continuous chlorination can be used with cellulose membranes to protect the system from biofouling and eliminate the particletrapping slime that worsens other forms of fouling such as scaling. Chlorine and other oxidizing disinfectants are harmful to thin film composite membranes. If the feed water is chlorinated, an activated carbon unit must be in place to remove the oxidizing chemicals before they reach the TFC membrane. Activated carbon (AC) prefilters should not be used on non-chlorinated water supplies because they provide a place for microorganisms to multiply and lead to increased bio-fouling of the RO membrane surface.

7.2.8.3 Feasibility of Reverse Osmosis (RO)

Factors Considered	Analysis	Proposition
User households/ Population (average 5.3 persons per HH in total)	2,497 households (1% of total) are using 26 functional systems, while 2 other systems are found potential	Due to negative environmental impact and inability to satisfy UNDP requirement of "Zero brine" or "slow brine release", this technological option has not been proposed for increasing safe drinking water coverage in the study area.
Availability/quantity and quality of water sources	The RO system is based on a desalination process and can use both surface (i.e. river) water and groundwater irrespective of salinity and other pollution to produce safe drinking water. There are few rivers flowing through some unions of the study area and these rivers could be a potential source of water for RO plant implementation, especially for the areas, where no safe ground water source is available for DTW installation or fresh pond available for PSF/ Sky-hydrant implementation.	
Climate Resilience	The RO technology is resilient to increasing levels of salinity in the river or ground water.	
Ease of Operation and Maintenance (O&M): Technical	The RO plant is a Hi-tech option which requires to be operated by a skilled operator and the smooth operation of the plant requires technical back-up support from its	

	supplier. The system is either operated by electricity and diesel generator in emergency situation. The O&M cost of RO system is comparatively higher than any other technologies due to costly treatment system and replacement of filter media. A strong institutional arrangement is required to keep RO plant operational.	
Social impact and acceptability	The RO water is regarded as high quality water and is socially acceptable. But due to cost factor, the RO is not a very popular option in the study area.	
Affordability of the users: Economic aspects	The capital cost of and RO plant has been estimated at BDT 4,200,000 which can serve 200-250 households for supply of safe drinking water. The cost is high and it requires to be operated by private sector. The RO water is currently sold in saline area at a cost of BDT 0.5-1 per liter (20-30 liter per household per day) including cost of transportation by water vendors. To make the cost affordable by the Poor and "Extreme Poor", the cost need to be reduced, which is possible by increasing RO water supply coverage i.e. by ensuring optimum utilisation of RO plant capacity	
Health impacts	The RO water is of high quality, which is chemically and bacteriologically safe for drinking, and therefore, not harmful for either personal or public health	
Environmental impacts	RO plant generates hazardous waste (brine solution) that could affect the receiving bodies, if adequate preventive measures are not taken. As the brine that will be generated every day from the RO plant will contain high salinity (60% higher than feed water), the brine should not be disposed directly into fresh water bodies or in a place where living species can be affected. Therefore, it is recommended that these plants should be installed nearby river to facilitate easy disposal of brine water into the rivers at a slow rate so that the tidal flow of the river can flush away this brine quickly.	

7.3 Proposed Technology and Selection Methodology

Considering technical, environmental and social sustainability of above water technologies, following options were considered in the study as potential options to fulfil the demand of drinking water in 39 Unions in 5 Upazilas of Satkhira and Khulna district:

- Household based rainwater harvesting system
- Community based rainwater harvesting system
- Institution based rainwater harvesting system
- Community based sky-hydrant system for treatment of water from fresh water ponds, where available

After selecting the target wards (based on salinity, elevation and poverty as per livelihoods), the remaining steps to calculate the target households per ward and the appropriate water solutions to cover the target households were as follows:

For each ward, subtract the households with existing functioning safe water supply from the total ward population.

Multiply the remaining households without safe water supply in each ward by the zone factor where the zone factor is based on whether there are other proposed water supply improvement programmes in that sub-district. The known water supply improvement programmes in the Khulna and Sathkira districts are the World Vision Nobo Jatra Project and the Oh Horizon programme targeting marginalised households. The zone factors for each sub-district are as follows:

- The factor for Zone 1 is 50% on the following basis: Zone 1 includes wards in the sub-districts of Shyamnagar, Dacop, Koyra. The combined programmes from World Vision and Oh Horizon will implement drinking water solutions targeting 50% of the demand-supply gap in these sub-districts. World Vision's Nobo Jatra Project is proposing to install community level water solutions in 30% of the households. Oh Horizon is targeting 20% of the households and is proposing to install household level water solutions.

- The factor for Zone 2 is 100% on the following basis: Zone 2 includes wards in the sub-districts of Assasuni and Paikgacha. Neither World Vision nor Oh Horizon are planning to implement drinking water improvements in these sub-districts.

The proposed drinking water supply solutions were then prioritised for the target households based on the following list in descending order of priority:

1. Community level water treatment of pond water using improved pond sand filter design (and including raising embankments)
2. Medium (25 households) and large (50 households) scale RWH at existing institutional buildings (primarily in institutions such as schools, colleges, Union Councils and other government institutions)
3. Medium and large scale RWH at existing community buildings (primarily at community buildings such as mosques, temples, cyclone centres, community clinics and other private owned buildings used for community purposes)
4. Household level RWH for people with no access to community or institution based RWHS, especially people living far away from these systems, people with disability and ethnic minority groups. At least 20% of total target households will be covered by household based systems.
5. Large scale RWH at new community roofs. At each ward, maximum of 5 community RWHS with new roofs have been proposed, if the number of households remain uncovered even after above four types of water options.
6. If the target households still cannot be covered after step 5, then the remaining households will be provided with household based RWHS.

In a number of wards in the Zone 1 sub-districts, there are higher household figures being targeted for livelihoods than for water supply improvements, due to the existing safe water supplies and the proposed water supply improvements by World Vision. The households being supported with livelihood interventions will have water security, whether through the project or otherwise. Household level RWH will also be installed at households living far from the water sources and/or those who have accessibility issues (elderly people, person with disabilities, bad access roads, etc.).

8. Upazila Profiles and Proposed Water Technologies

8.1 Upazila: Shyamnagar

8.1.1 Background (geography, socio-economic)

Map of Shaymnagar Upazila

Shyamnagar Upazila of Shatkhira district is situated in the southern part of Satkhira district adjacent to World famous mangrove forest 'Sundarban'. The total area of the union is 1968 sq.km. The union is situated 78 km away from District HQ. The union is surrounded by Kaliganj in the North, Shunderban in the South, Kapatakha and Kholpetua river in the East and Raimangal river in the West. Besides, Jamuna, Chuna, Malancha and Madar rivers are flowing through Shaymnagar. The important rivers flowing through this union are Kholpetia, Chuna and Kadamtala. There are 15 public fresh water bodies in the union. As per estimate in the PRA sessions, the population of Burigoalini was estimated at **308,864** (M: **150,777** F: **153,587**) and household at **58,721**. The ward wise population is presented in Table 17 below:

Table 17: Demographic information of Shyamnagar Upazila

Union	Total number of Ward	Total Number of village	Total Number of HH	Population		
				Female	Male	Total
Atulia	9	34	8,621	22,876	22,086	44,962
Ramjannagar	9	14	5,827	15,139	15,705	30,844
Kashimari	9	16	7,994	19,338	18,800	38,138
Burigoalini	9	24	6,753	22,006	23,780	45,786
Gabura	9	17	7,486	20,300	18,857	39,157
Kaikhali	9	18	6,409	16,248	15,982	32,230
Padmapukur	9	12	6,316	15,115	14,752	34,367
Munshiganj	9	19	9,315	22,565	20,815	43,380
Total:	**72**	**154**	**58,721**	**153,587**	**150,777**	**308,864**

8.1.2 Drinking Water Sources, Supply, and Access

From analyses of the information collected during PRA process and expert judgment by the technical team, current drinking water supply options of Shaymnagar upazilla were identified. There were three major sources of drinking water in the Union which are rainwater, groundwater from a shallow aquifer, and pond water.

Each existing drinking water source was classified as either functioning or potential. The definitions for these are as follows:

- Functioning
- Potential

Among these three sources, rainwater is conventionally harvested by the households for drinking purpose during the rainy season. Since rainfall in Bangladesh is abundant, local people can use rainwater for drinking and cooking purposes during the rainy season. They use the rooftop as catchment and store rainwater in reservoirs. Rainwater is popular among women as they can store water in their houses and do not need to go outside for collection. However, although rainwater quality is good, stored rainwater often gets contaminated due to poor maintenance of catchment and unhygienic storage system. It was reported during the PRA session that people in this area do not use any disinfection system. As previous studies suggest that rainwater stored in rural areas often contain bacteriological contamination[71], this is a limitation of this technology if used without any disinfection system as it may have negative health impacts. In addition, absence of rainfall during winter and early part of the pre-monsoon makes storing water for the dry season difficult for people of Shaymnagar Upazila. Most of the households do not have large rainwater reservoirs, as these are too expensive for them. Therefore, rainwater being currently used at household level during rainy season provides a dependable solution for the whole year if rainwater tanks with large storage capacity can be made available to local people. In addition, awareness raising on safe use of rainwater and maintenance of the system will help ensuring water safety at the user's end. There are a total 1,577 household based RWHS in Shaymnagar Upazila which covers only 2.7% households of the Upazila.

In 5 Union, there is a source of fresh groundwater that provides drinking water to the community by extraction through deep hand tubewell (DHTW). A total of 382 household based functional DHTWS and 791 community based functional DHTW in Shaymnagar Upazila cover 9634 households (17.05%). These DHTW provide water round the water and reduces the collection time and effort of the woman substantially in those 5 unions. However, salinity intrusion in the deep layer is perceived to be the main threat of climate change in these areas. There are 22 piped water supply schemes based on ground supply in 4 unions of Shaymnagar Upazila, which provide drinking water supply to 1680 households (2.86%). Piped water supply provides water supply at the door step of the households and substantially reduces collection effort of the women. But water quality of these piped water schemes is not up to the mark and water supply is not also regular.

In areas where fresh water ponds are available, people depend on pond water, especially during dry season when rainwater is not available. But fresh water ponds are very scarce in Shaymnagar Union and people, especially women, are seen to collect pond water from a distance of 2 to 3 kilometers. Due to a lack of adequate maintenance, these ponds are found vulnerable to pollution. But absence of any other sources makes a large number of households dependent on this unsafe source for drinking water. In some households, alum is used in pond water which fastens precipitation of suspended particles, though it does not effectively remove bacteriological contamination from water. For treatment of pond water, pond sand filters (PSFs) are often proposed in coastal areas. There are 118 functional pond sand filters (PSF) based on these fresh ponds, which provides drinking water to 5,715 households (9.73%) of Shaymnagar. But it was observed in the study area that due to operational and maintenance difficulties (cleaning of filter beds, lifting of water into the filter chambers, lack of repair/maintenance funds, etc.) these PSFs do not sustain. It was also reported by the local communities in Shaymnagar that a large number of PSFs installed in the Union are currently non-functional (54%).

[71] Karim et. al., 2016

There are 9 Reverse Osmosis (RO) plants in 4 unions of Shaymnagar upazila which provides water supply to 862 households (1.47%). These RO plants are operated by different NGOs on business model in extreme salinity affected areas. But these RO plants fail to attract poor users to purchase water at a high price (0.5-1.0 per litre) and hence these are not operated at their optimal capacity. There is 1 MAR in Gabura union, which was installed by DPHE and is operating on pilot basis.

All the above technological options provides drinking water supply to 20,082 households and the supply coverage is 34.2%. Still there is supply gap of 65.8% in Shaymnagar upazila. Existing water supply technologies, coverage and supply gap of Shaymnagar Upazila is shown in Table 18.

Table 18: Existing water supply technologies, coverage and supply gap of Shyamnagar Upazila

Union	Total number of ward	Total Number of village	Total Number of HH	Existing Household based drinking water technology					Existing Community based drinking water technology																					Total HH covered (HH & Community)	Coverage (%)	Uncovered HH	Supply gap (%)
				DHTW		RWH		Total	Deep set Hand Tube well (DHTW)			Pond Sand Filter (PSF)			Rain Water Harvesting (RWH)			Reverse Osmosis (RO)			Piped Water Supply (PWS)			Others (MAR)			Total P options	Total P options	Total HH covered				
				Functional	Potential	Functional	Potential		Functional	Potential	HH covered	Functional	Potential	HH covered	Functional	Potential	HH covered	Functional	Potential	HH covered	Functional	Potential	HH covered	Functional	Potential	HH covered							
Atulia	9	34	8,621	32	70	469	5	501	47	11	550	9	16	275	15	-	64	1	-	25	1	-	450	-	-	-	73	27	1,364	1,865	21.6	6,756	78.4
Ramjan Nagar	9	14	5,827	-	-	128	1	128	39	4	450	13	22	1,375	3	-	15	-	-	-	-	-	-	-	-	-	55	26	1,840	1,968	33.8	3,859	66.2
Kashimari	9	16	7,994	234	-	29	-	263	387	17	3,811	11	3	425	-	-	-	-	-	-	10	-	700	-	-	-	408	20	4,936	5,199	65.0	2,795	35.0
Burigoalini	9	24	6,753	-	-	395	-	395	-	-	-	15	24	690	7	-	35	5	1	380	-	1	-	-	-	-	27	26	1,105	1,500	22.2	5,253	77.8
Gabura	9	17	7,486	62	-	264	14	326	69	4	745	7	17	140	4	5	20	2	-	422	1	-	280	1	-	50	84	26	1,657	1,983	26.5	5,503	73.5
Kaikhali	9	18	6,409	-	-	98	-	98	39	-	446	42	23	1,760	2	3	24	-	-	-	-	-	-	-	-	-	83	26	2,230	2,328	36.3	4,081	63.7
Padmapukur	9	12	6,316	4	5	55	-	59	144	11	2,112	1	7	50	-	-	-	-	-	-	6	-	150	-	-	-	151	18	2,312	2,371	37.5	3,945	62.5
Munshiganj	9	19	9,315	50	40	139	-	189	66	-	1,520	20	26	1,000	6	-	24	1	-	35	4	-	100	-	-	-	97	26	2,679	2,868	30.8	6,447	69.2
Total	**72**	**154**	**58,721**	**382**	**115**	**1577**	**20**	**1959**	**791**	**47**	**9,634**	**118**	**138**	**5,715**	**37**	**8**	**182**	**9**	**1**	**862**	**22**	**1**	**1,680**	**1**	**0**	**50**	**978**	**195**	**18,123**	**20,082**	**34.2**	**38,639**	**65.8**

8.1.4 Proposed Water Technologies

The proposed water technologies, quantity and cost for proposed technologies are given in Table 19:

Table 19: Proposed water technologies in Shyamnagar Upazila

Union	Ward No.	Number of HH	# of HH with existing functioning safely managed water supplies	Target Households (50% of HH without safely managed water supplies)	Proposed Technology						
					HH based RWHS	Community based RWHS			Institution based RWHS		PSF
						in existing buildings		in new locations			
						Medium Tanks (25 HHs)	Large Tanks (50 HHs)	Large Tanks (50 HHs)	Medium Tanks (25 HHs)	Large Tanks (50 HHs)	
Atulia	4	1,130	125	503	153		2	5			
Atulia	5	750	45	353	71						2
Atulia	7	404	167	119	24						1
Atulia	8	750	114	318	68		1				1
		3,034	451	1,292	315	-	3	5	-	-	4
Ramjan Nagar	4	851	200	326	76		1				1
Ramjan Nagar	9	782	400	191	41			3			
		1,633	600	517	117	-	1	3	-	-	1
Kashimari	6	833	713	60	10		1	-			
Kashimari	9	545	321	112	62			1			
		1,378	1,034	172	72	-	1	1	-	-	-
Burigoalini	1	875	142	367	67		1			1	1
Burigoalini	4	565	334	116	23						1
Burigoalini	7	1,000	130	435	87						2
		2,440	606	917	177	-	1	-	-	1	4

Union	Ward No.	Number of HH	# of HH with existing functioning safely managed water supplies	Target Households (50% of HH without safely managed water supplies)	Proposed Technology						
					HH based RWHS	Community based RWHS			Institution based RWHS		PSF
						in existing buildings		in new locations			
						Medium Tanks (25 HHs)	Large Tanks (50 HHs)	Large Tanks (50 HHs)	Medium Tanks (25 HHs)	Large Tanks (50 HHs)	
Gabura	4	672	330	171	34	1					1
Gabura	5	1,138	479	330	80			4		1	
Gabura	7	685	8	339	68						2
		2,495	817	839	181	1	-	4	-	1	3
Kaikhali	6	900	498	201	40					1	1
Kaikhali	8	434	274	80	16						1
		1,334	772	281	56	-	-	-	-	1	2
Padmapukur	3	600	375	113	13		1			1	
Padmapukur	4	845	170	338	68						2
Padmapukur	7	751	50	351	101			1			1
		2,196	595	801	181	-	1	1	-	1	3
Munshiganj	6	1,253	307	473	123		4			3	
Munshiganj	9	1,058	144	457	207			5			
		2,311	451	930	330	-	4	5	-	3	-
Total		**16,821**	**5,326**	**5,748**	**1,428**	**1**	**11**	**19**	**-**	**7**	**17**

8.2 Upazila: Assasuni

8.2.1 Background (geography, socio-economic)

Assasuni Upazila of Satkhira district is situated to the south east of Satkhira district with geographical location 22.5500°N 89.1681°E. The upazilla has 11 UPs of which 10 unions are covered under this study. The total area of the Assasuni is 367 sq.km. The upazilla is situated 27 km away from District HQ. The Upazilla is surrounded by Tala and Satkhira Sadar in the North, Assasuni in the South, Paikgacha and Koyra of Khulna district in the East and Kaliganj and Debhata in the West. Four rivers namely Maricchap, Khelna, Khelpetua and Kapotakkha are flowing through Assasuni. As per estimate in the PRA sessions at the union level, the population of Assasuni was estimated at **400,009** (M: **200,275** F: **199,734**) and household at **73,199**. The union wise population is presented in below:

Table 20: Demographic information of Assasuni Upazila

Union	Total number of ward	Total Number of village	Total Number of HH	Population		
				Female	Male	Total
Anulia	9	24	8,380	21,750	21,450	43,200
Durgapur	9	14	5,730	16,895	16,925	33,820
Sreeula	9	23	7,791	19,519	19,290	38,809
Budhata	9	24	8,955	29,680	28,420	58,100
Barodal	9	23	9,028	23,650	21,980	45,630
Khajra	9	26	7,121	19,850	18,925	38,775
Kulla	9	21	7,085	18,950	19,680	38,630
Kadakati	9	24	4,323	10,960	11,760	22,720
Assasuni	9	25	6,690	17,970	20,530	38,500
Protap Nagar	9	18	8,096	20,510	21,315	41,825
	72	**222**	**73,199**	**199,734**	**200,275**	**400,009**

8.2.2 Drinking Water Sources, Supply, and Access

From analyses on the information collected during PRA process and expert judgment by the technical team, current drinking water supply options of Assasuni upazila were identified. There were three major sources of drinking water in the Union which are rainwater, groundwater from a shallow aquifer, and pond water. Among these three sources, rainwater is conventionally harvested by the households for drinking purpose during the rainy season. Since rainfall in Bangladesh is abundant, local people can use rainwater for drinking and cooking purposes during the rainy season. They use the rooftop as catchment and store rainwater in reservoirs. Rainwater is popular among women as they can store water in their houses and do not need to go outside for collection. However, although rainwater quality is good, stored rainwater often gets contaminated due to poor maintenance of catchment and unhygienic storage system. It was reported during the PRA session that people in this area do not use any disinfection system. As previous studies suggest that rainwater stored in rural areas often contain bacteriological contamination[72], this is a limitation of this technology if used without any disinfection system as it may have negative health impacts. In addition, absence of rainfall during winter and early part of the pre-monsoon makes storing water for the dry season difficult for people of Assasuni Upazila. Most of the households do not have large rainwater reservoirs, as these are too expensive for them. Therefore, rainwater being currently used at household level during rainy season provides a dependable solution for the whole year if rainwater tanks with large storage capacity can be made available to local people. In addition, awareness raising on safe use of rainwater and maintenance of the system will help ensuring water safety at the user's end. There are a total 779 household based RWHS in Assasuni Upazila which covers only 1.06% households of the Upazila.

In 8 Union, there is a source of fresh groundwater that provides drinking water to the community by extraction through deep hand tubewell (DHTW). A total of 323 household based functional DHTWs and 394 community based functional DHTW in Assasuni Upazila cover 4,944 households (6.75%). These DHTW provide water round the water and reduces the collection time and effort of the woman substantially in those 8 unions. However, salinity intrusion in the deep layer is perceived to be the main threat of climate change in these areas. There are 3 piped water supply schemes based on ground supply in 2 unions of Assasuni Upazila, which provide drinking water supply to 1295 households (1.77%). Piped water supply provides water supply at the door step of the households and substantially reduces collection effort of the women. But water quality of these piped water schemes is not up to the mark and water supply is not also regular.

In areas where fresh water ponds are available, people depend on pond water, especially during dry season when rainwater is not available. But fresh water ponds are very scarce in Assasuni Union and people, especially women, are seen to collect pond water from a distance of 3 to 5 kilometers. Due to a lack of adequate maintenance, these ponds are found vulnerable to pollution. But absence of any other sources makes a large number of households dependent on this unsafe source for drinking water. In some households, alum is used in pond water which fastens precipitation of suspended particles, though it does not effectively remove bacteriological contamination from water. For treatment of pond water, pond sand filters (PSFs) are often proposed in coastal areas. There are 69 functional pond sand filters (PSF) based on these fresh ponds, which provides drinking water to 4,182 households (5.71%) of Assasuni. But it was observed in the study area that due to operational and maintenance difficulties (cleaning of filter beds, lifting of water into the filter chambers, lack of repair/maintenance funds, etc.) these PSFs do not sustain. It was also reported by the local communities in Assasuni that a large number of PSFs installed in the Union are currently non-functional (45%).

There are 13 Reverse Osmosis (RO) plants in 5 unions of Assasuni upazila which provides water supply to 1375 households (1.88%). These RO plants are operated by different NGOs on business model in extreme salinity affected areas. But these RO plants fail to attract poor users to purchase water at a high price (0.5-1.0 per litre) and hence these are not operated at their optimal capacity.

[72] Karim et. al., 2016

All the above technological options provide drinking water supply to 12,759 households and the supply coverage is 17.6%. Still there is supply gap of 82.4% in Assasuni upazila. Existing water supply technologies, coverage and supply gap of Assasuni Upazila is shown in Table 21.

Table 21: Existing water supply technologies, coverage and supply gap of Assasuni Upazila

Union	Total number of ward	Total Number of village	Total Number of HH	Existing Household based drinking water technology					Existing Community based drinking water technology																					Total HH covered (HH & Community)	Coverage (%)	Uncovered HH	Supply gap (%)
				DHTW		RWH		Total	Deep set Hand Tube well (DHTW)			Pond Sand Filter (PSF)			Rain Water Harvesting (RWH)			Reverse Osmosis (RO)			Piped Water Supply (PWS)			Others (MAR)			Total P options	Total P options	Total HH covered				
				Functional	Potential	Functional	Potential		Functional	Potential	HH covered	Functional	Potential	HH covered	Functional	Potential	HH covered	Functional	Potential	HH covered	Functional	Potential	HH covered	Functional	Potential	HH covered							
Anulia	9	24	8,380	1	0	17	0	18	28	-	280	-	1	-	1	-	48	-	-	-	-	-	-	-	-	-	29	1	328	346	4.1	8,034	95.9
Durgapur	9	14	5,730	2	0	95	0	97	-	-	-	3	5	135	4	-	20	3	1	250	-	-	-	-	-	-	10	6	405	502	8.8	5,228	91.2
Sreeula	9	23	7,791	105	0	41	0	146	82	135	1,460	2	2	100	-	-	-	-	-	-	-	-	-	-	-	-	84	137	1,560	1,706	21.9	6,085	78.1
Budhata	9	24	8,955	0	0	87	0	87	2	1	40	10	5	500	4	-	16	5	-	290	1	-	50	-	-	-	22	6	896	983	11.0	7,972	89.0
Barodal	9	23	9,028	6	0	105	0	111	-	-	-	23	21	1,180	16	-	80	-	-	-	-	-	-	-	-	-	39	21	1,260	1,371	15.2	7,657	84.8
Khajra	9	26	7,121	0	0	104	0	104	-	-	-	6	2	300	-	-	-	-	-	-	-	-	-	-	-	-	6	2	300	404	5.7	6,717	94.3
Kulla	9	21	7,085	142	0	43	0	185	1	-	50	14	4	765	-	-	-	2	-	480	-	-	-	-	-	-	17	4	1,295	1,480	20.9	5,605	79.1
Kadakati	9	24	4,323	2	0	147	0	149	1	-	25	7	12	327	1	2	20	2	-	155	-	-	-	-	-	-	11	14	527	676	15.6	3,647	84.4
Assasuni		25	6,690	16	0	101	5	117	42	2	386	4	4	875	-	-	-	1	-	200	2	-	1,245	-	-	-	629	6	2,706	2,823	42.2	3,867	57.8
Protap Nagar		18	8,096	49	0	39	0	88	238	3	2,380	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	238	4	2,380	2,468	30.5	5,628	69.5
Total	**72**	**222**	**73,199**	**323**	**0**	**779**	**5**	**1,102**	**394**	**141**	**4,621**	**69**	**57**	**4,182**	**26**	**2**	**184**	**13**	**1**	**1,375**	**3**	**-**	**1,295**	**-**	**-**	**-**	**1,085**	**201**	**11,657**	**12,759**	**17.6**	**60,440**	**82.4**

8.2.3 Proposed water solutions

The proposed water technologies are given in Table 22.

Table 22: Proposed water technologies in Assasuni Upazila

Union	Ward No.	Number of HH	# of HH with existing functioning safely managed water supplies	Target Households (100% of HH without safely managed water supplies)	Proposed Technology						
					HH based RWHS	Community based RWHS			Institution based RWHS		PSF
						in existing buildings		in new locations			
						Medium Tanks (25 HHs)	Large Tanks (50 HHs)	Large Tanks (50 HHs)	Medium Tanks (25 HHs)	Large Tanks (50 HHs)	
Anulia	2	560	4	556	256	1		5	1		
Anulia	4	700	-	700	400			5	2		
Anulia	7	2,100	22	2,078	1,803			5	1		
Anulia	9	650	261	389	114	1		4	2		
		4,010	287	3,723	2,573	2	-	19	6	-	-
Durgapur	4	1,100	159	941	191			5		2	2
Durgapur	6	700	78	622	172		1	2		2	1
Durgapur	9	475	49	426	126			5		1	
		2,275	286	1,989	489	-	1	12	-	5	3
Sreeula	1	865	15	850	500			5		2	
Sreeula	2	390	9	381	81			4		2	
Sreeula	4	**950**	297	653	153		1	1			2
		2,205	321	1,884	734	-	1	10	-	4	2
Budhata	1	1,100	175	925	225	3		4	1		2
Budhata	2	500	15	485	110	3		5	2		
Budhata	8	940	103	837	262	1		5		2	1

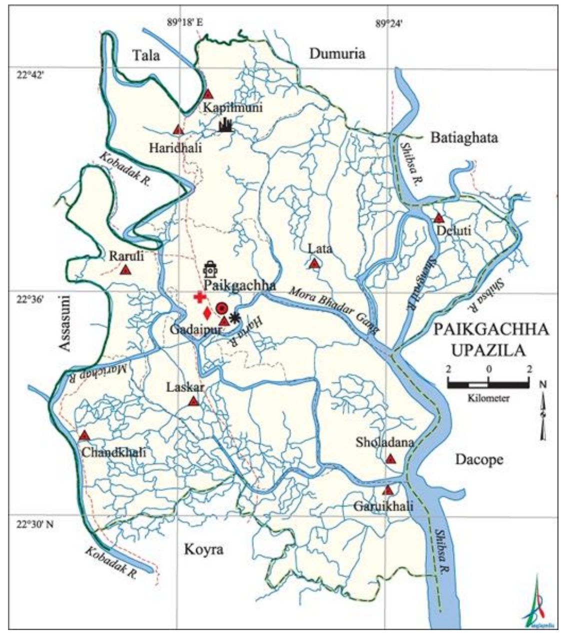
Union	Ward No.	Number of HH	# of HH with existing functioning safely managed water supplies	Target Households (100% of HH without safely managed water supplies)	Proposed Technology						
					HH based RWHS	Community based RWHS			Institution based RWHS		PSF
						in existing buildings		in new locations			
						Medium Tanks (25 HHs)	Large Tanks (50 HHs)	Large Tanks (50 HHs)	Medium Tanks (25 HHs)	Large Tanks (50 HHs)	
		2,540	293	2,247	597	7	-	14	3	2	3
Bardal	1	498	151	347	72			5	1		
Bardal	4	1,550	20	1,530	830			5		1	2
Bardal	7	1,025	162	863	238			5	1	3	1
		3,073	333	2,740	1,140	-	-	15	2	4	3
Khajra	2	750	22	728	378			5		2	
Khajra	3	920	116	804	504			5		1	
Khajra	9	900	109	791	391			5		3	
		2,570	247	2,323	1,273	-	-	15	-	6	-
Kulla	5	740	350	390	90			5		1	
Kulla	6	600	66	534	134			2		2	1
Kulla	9	450	38	412	112			2		4	
		1,790	454	1,336	336	-	-	9	-	7	1
Kadakati	2	395	92	303	53			0		1	1
Kadakati	3	321	45	276	76		1	2		1	
Kadakati	5	250	91	159	32						1
		966	228	738	161	-	1	2	-	2	2

Union	Ward No.	Number of HH	# of HH with existing functioning safely managed water supplies	Target Households (100% of HH without safely managed water supplies)	Proposed Technology						
					HH based RWHS	Community based RWHS			Institution based RWHS		PSF
						in existing buildings		in new locations			
						Medium Tanks (25 HHs)	Large Tanks (50 HHs)	Large Tanks (50 HHs)	Medium Tanks (25 HHs)	Large Tanks (50 HHs)	
Assasuni	2	470	392	78	28			0		1	
Assasuni	9	550	45	505	230			5	1		
		1,020	437	583	258	-	-	5	1	1	-
Protapnagar	6	750	400	350	100			1			1
Protapnagar	7	1,300	255	1,045	595		1	5		3	
Protapnagar	8	650	173	477	127		1	5		1	
		2,700	828	1,872	822	-	2	11	-	4	1
Total		**23,149**	**3,714**	**19,435**	**8,383**	**9**	**5**	**112**	**12**	**35**	**15**

8.3 Upazila: Paikgacha

8.3.1 Background (geography, socio-economic)

Paikgacha upazila is situated between 22°28' and 22°43' north latitudes and in between 89°14' and 89°28' east longitudes. It is bounded by Tala and Dumuria upazilas on the north, Koyra upazila on the south, Batiaghata and Dacop upazilas on the east, Tala and Assasuni upazilas on the west. The upazilla is 65 km away from Khulna district. Total population of Paikgacha upazila is **160,310**; male **84,510**, female **75,800**; Main rivers of Paikgacha upazila are Kobadak, Shibsa, Marichap, Haria, Shengrail, Mora Bhadar Gang.



Main sources of income are agriculture 53.14%, non-agricultural labor 5.48%, industry 1.50%, commerce 22.93%, transport and communication 2.82%, service 4.11%, construction 1.16%, religious service 0.21%, rent and remittance 0.12% and others 8.53%.

Table 23: Demographic information of Paikgacha Upazila

Union	Total Number of village	Total Nos. of Households	Population		
			Female	Male	Total
Deluti	23	4,182	10,410	13,975	24,385
Lata	23	3,850	9,725	9,305	19,030
Chandkhali	31	7,340	17,180	19,520	36,700
Garaikhali	15	8,436	22,920	21,960	44,880
Soladana	33	5,829	15,565	19,750	35,315
	125	**29,637**	**75,800**	**84,510**	**160,310**

8.3.2 Drinking Water Sources, Supply, and Access

From analyses on the information collected during PRA process and expert judgment by the technical team, current drinking water supply options of Paikgacha upazila were identified. There were three major sources of drinking water in the Union which are rainwater, groundwater from a shallow aquifer, and pond water.

Each existing drinking water source was classified as either functioning or potential. The definitions for these are as follows:

- Functioning
- Potential

Among these three sources, rainwater is conventionally harvested by the households for drinking purpose during the rainy season. Since rainfall in Bangladesh is abundant, local people can use rainwater for drinking and cooking purposes during the rainy season. They use the rooftop as catchment and store rainwater in reservoirs. Rainwater is popular among women as they can store water in their houses and do not need to go outside for collection. However, although rainwater quality is good, stored rainwater often gets contaminated due to poor maintenance of catchment and unhygienic storage system. It was reported during the PRA session that people in this area do not use any disinfection system. As previous studies suggest that rainwater stored in rural areas often contain bacteriological contamination[73], this is a limitation of this technology if used without any disinfection system as it may have negative health impacts. In addition, absence of rainfall during winter and early part of the pre-monsoon makes storing water for the dry season difficult for people of Paikgacha Upazila. Most of the households do not have large rainwater reservoirs, as these are too expensive for them. Therefore, rainwater being currently used at household level during rainy season provides a dependable solution for the whole year if rainwater tanks with large storage capacity can be made available to local people. In addition, awareness raising on safe use of rainwater and maintenance of the system will help ensuring water safety at the user's end. There are a total 427 household based functional RWHS and 28 community based functional RWHS in Paikgacha Upazila which covers 567 households (1.91%).

In 2 Unions, there is a source of fresh groundwater that provides drinking water to the community by extraction through deep hand tubewell (DHTW). A total of 33 household based functional DHTWs and 2 community based functional DHTW in Paikgacha Upazila cover only 193 households (0.65%). These DHTW provide water round the water and reduces the collection time and effort of the woman substantially in the above 2 unions. However, salinity intrusion in the deep layer is perceived to be the main threat of climate change in these areas. There are 6 piped water supply schemes based on ground supply in 2 unions of Paikgacha Upazila, which provide drinking water supply to 521 households (1.76%). Piped water supply provides water supply at the door step of the households and substantially reduces collection effort of the women. But water quality of these piped water schemes is not up to the mark and water supply is not also regular

In areas where fresh water ponds are available, people depend on pond water, especially during dry season when rainwater is not available. But fresh water ponds are very scarce in Paikgacha Union and people, especially women, are seen to collect pond water from a distance of 2 to 3 kilometers. Due to a lack of adequate maintenance, these ponds are found vulnerable to pollution. But absence of any other sources makes a large number of households dependent on this unsafe source for drinking water. In some households, alum is used in pond water which fastens precipitation of suspended particles, though it does not effectively remove bacteriological contamination from water. For treatment of pond water, pond sand filters (PSFs) are often proposed in coastal areas. There are 7 functional pond sand filters (PSF) based on these fresh ponds, which provides drinking water to 427 households (1.44%) of Paikgacha. But it was observed in the study area that due to operational and maintenance difficulties (cleaning of filter beds, lifting of water into the filter chambers, lack of repair/maintenance funds, etc.) these PSFs do not sustain. It was also reported by the local communities in Paikgacha that a large number of PSFs installed in the Union are currently non-functional (62%).

There is 3 MAR in Paikgacha, which was installed by DPHE and is operating on pilot basis which covers 260 households (0.88%).

[73] Karim et. al., 2016

All the above technological options provides drinking water supply to 27,669 households and the supply coverage is only 7.06%. Still there is a huge supply gap of 92.94% in Paikgacha upazila.

Table 24: Existing water supply technologies, coverage and supply gap of Paikgacha Upazila

Union	Total number of ward	Total Number of village	Total Number of HH	Existing Household based drinking water technology					Existing Community based drinking water technology																						Total HH covered (HH & Community)	Coverage (%)	Uncovered HH	Supply gap (%)
				DHTW		RWH		Total	Deep set Hand Tube well (DHTW)			Pond Sand Filter (PSF)			Rain Water Harvesting (RWH)			Reverse Osmosis (RO)			Piped Water Supply (PWS)			Others (MAR)			Total P options	Total P options	Total HH covered				
				Functional	Potential	Functional	Potential		Functional	Potential	HH covered	Functional	Potential	HH covered	Functional	Potential	HH covered	Functional	Potential	HH covered	Functional	Potential	HH covered	Functional	Potential	HH covered							
Deluti	9	23	4,182	0	0	36	0	36	0	0	0	2	8	57	1	0	30	0	0	0	1	0	321	1	1	100	5	9	508	544	13.01	3638	86.99
Lata	9	23	3,850	0	0	81	1	81	0	0	0	1	0	20	0	0	0	0	0	0	0	0	0	0	0	0	1	0	20	101	2.62	3749	97.38
Chandkhali	9	31	7,340	1	0	10	0	11	1	0	100	2	3	200	0	0	0	0	0	0	0	0	0	1	0	100	4	3	400	411	5.60	6929	94.40
Garaikhali	9	15	8,436	0	0	230	0	230	0	0	0	0	0	0	2	0	10	0	0	0	0	0	0	1	0	60	3	0	70	300	3.56	8136	96.44
Soladana	9	33	5,829	32	0	70	0	102	1	0	60	2	2	150	25	0	100	0	0	0	5	0	200	0	0	0	33	2	510	612	10.50	5217	89.50
Total	45	125	29,637	33	-	427	1	460	2	-	160	7	13	427	28	-	140	-	-	-	6	-	521	3	1	260	46	14	1,508	1,968	7.06	27,669	92.94

8.3.3 Proposed water solutions

The proposed water technologies are given in Table 25.

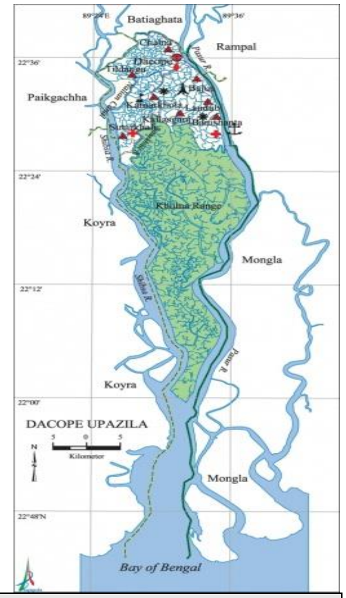
Table 25: Proposed water technologies in Paikgacha Upazila

Union	Ward No.	Number of HH	# of HH with existing functioning safely managed water supplies	Target Households (100% of HH without safely managed water supplies)	Proposed Technology						
					HH based RWHS	Community based RWHS			Institution based RWHS		PSF
						in existing buildings		in new locations			
						Medium Tanks (25 HHs)	Large Tanks (50 HHs)	Large Tanks (50 HHs)	Medium Tanks (25 HHs)	Large Tanks (50 HHs)	
Deluti	1	486	31	455	130			5	1	1	
Deluti	5	427	303	124	24	1		-	1	1	
Deluti	6	427	26	401	151			5			
		1,340	360	980	305	1	-	10	2	2	-
Lata	3	350	7	343	93	1		4	1		
Lata	4	365	5	360	110			4	2		
		715	12	703	203	1	-	8	3	-	-
Chandkhali	1	900	1	899	399	2	2	5		2	
Chandkhali	2	820	-	820	295	2	1	5	1	3	
Chandkhali	3	400	5	395	120	1		4	2		
		2,120	6	2,114	814	5	3	14	3	5	-
Garaikhali	3	1,000	12	988	738			5			
Garaikhali	7	1,215	14	1,201	951			5			
		2,215	26	2,189	1,689	-	-	10	-	-	-
Soladana	3	710	236	474	174			5	2		
Soladana	6	394	-	394	119			5	1		
		1,104	236	868	293	-	-	10	3	-	-

Union	Ward No.	Number of HH	# of HH with existing functioning safely managed water supplies	Target Households (100% of HH without safely managed water supplies)	Proposed Technology						
					HH based RWHS	Community based RWHS			Institution based RWHS		PSF
						in existing buildings		in new locations			
						Medium Tanks (25 HHs)	Large Tanks (50 HHs)	Large Tanks (50 HHs)	Medium Tanks (25 HHs)	Large Tanks (50 HHs)	
Total		**7,494**	**640**	**6,854**	**3,304**	**7**	**3**	**52**	**11**	**7**	**-**

8.4 Upazila: Dacope

8.4.1 Background (geography, socio-economic)



Dacope Upazila (Khulna district) area 991.57 sq km, located in between 22°24' and 22°40' North latitudes and in between 89°24' and 89°35' east longitudes. It is bounded by Batiaghata upazila on the North, Pasur river on the South, Rampal and Mongla upazilas on the East, Paikgachha and Koyra upazilas on the West. Water bodies Main rivers: Pasur, shibsa, Manki, bhadra; Palashbari, Churia, Nalian and Jugra canals are notable. Total population of Dacope upazila is **165,975**; male **92,539** and female **89,518**.

Main sources of income Agriculture 66.07%, non-agricultural laborer 4.85%, commerce 12.86%, transport and communication 1.72%, service 4.10%, construction 0.93%, religious service 0.24%, rent and remittance 0.05% and others 9.18%.

Table 26: Demographic information of Dacope Upazila

Union	Total Number of village	Total Nos. of Households	Population		
			Female	Male	Total
Dacope Sadar	12	1,943	5,625	5,875	11,500
Bajua	20	4,103	9,809	10,431	20,240
Bani Shanta	15	4,102	12,620	12,900	25,520
Suterkhali	13	3,868	9,345	9,801	19,146
Pankhali	11	4,400	9,956	10,379	20,335
Til Danga	12	4,722	11,846	12,605	24,451
Kamarkhol	19	3,329	7,383	7,217	16,036
Lawdob	34	6,372	13,589	13,530	9,601
Kailashganj	13	3,868	9,345	9,801	19,146
9	149	36,707	89,518	92,539	165,975

8.4.2 Drinking Water Sources, Supply, and Access (Upazila specific)

From analyses on the information collected during PRA process and expert judgment by the technical team, current drinking water supply options of Dacope upazila were identified. There were three major sources of drinking water in the Union which are rainwater, groundwater from a shallow aquifer, and pond water.

Each existing drinking water source was classified as either functioning or potential. The definitions for these are as follows:

- Functioning
- Potential

Among these three sources, rainwater is conventionally harvested by the households for drinking purpose during the rainy season. Since rainfall in Bangladesh is abundant, local people can use rainwater for drinking and cooking purposes during the rainy season. They use the rooftop as catchment and store rainwater in reservoirs. Rainwater is popular among women as they can store water in their houses and do not need to go outside for collection. However, although rainwater quality is good, stored rainwater often gets contaminated due to poor maintenance of catchment and unhygienic storage system. It was reported during the PRA session that people in this area do not use any disinfection system. As previous studies suggest that rainwater stored in rural areas often contain bacteriological contamination[74], this is a limitation of this technology if used without any disinfection system as it may have negative health impacts. In addition, absence of rainfall during winter and early part of the pre-monsoon makes storing water for the dry season difficult for people of Dacope Upazila. Most of the households do not have large rainwater reservoirs, as these are too expensive for them. Therefore, rainwater being currently used at household level during rainy season provides a dependable solution for the whole year if rainwater tanks with large storage capacity can be made available to local people. In addition, awareness raising on safe use of rainwater and maintenance of the system will help ensuring water safety at the user's end. There are a total 1523 household based functional RWHS and 47 community based functional RWHS in Dacope Upazila which covers 1733 households (4.72%).

In 5 Union, there is a source of fresh groundwater that provides drinking water to the community by extraction through deep hand tubewell (DHTW). A total of 2 household based functional DHTWS and 31 community based functional DHTW in Dacope Upazila covering 526 households (1.43%). These DHTW provide water round the water and reduces the collection time and effort of the woman substantially in those 5 unions. However, salinity intrusion in the deep layer is perceived to be the main threat of climate change in these areas. There are 2 piped water supply schemes based on ground supply in 2 unions of Dacope Upazila, which provide drinking water supply to 200 households (0.54%). Piped water supply provides water supply at the door step of the households and substantially reduces collection effort of the women. But water quality of these piped water schemes is not up to the mark and water supply is not also regular.

In areas where fresh water ponds are available, people depend on pond water, especially during dry season when rainwater is not available. But fresh water ponds are very scarce in Dacope Union and people, especially women, are seen to collect pond water from a distance of 2 to 3 kilometers. Due to a lack of adequate maintenance, these ponds are found vulnerable to pollution. But absence of any other sources makes a large number of households dependent on this unsafe source for drinking water. In some households, alum is used in pond water which fastens precipitation of suspended particles, though it does not effectively remove bacteriological contamination from water. For treatment of pond water, pond sand filters (PSFs) are often proposed in coastal areas. There are 94 functional pond sand filters (PSF) based on these fresh ponds, which provides drinking water to 3867 households (10.53%) of Dacope. But it was observed in the study area that due to operational and maintenance difficulties (cleaning of filter beds, lifting of water into the filter chambers, lack of repair/maintenance funds, etc.) these PSFs do not sustain. It was also reported by the local communities in Dacope that a large number of PSFs installed in the Union are currently non-functional (48%).

There are 2 Reverse Osmosis (RO) plants in 2 unions of Dacope upazila which provides water supply to 150 households (0.41%). These RO plants are operated by different NGOs on business model in extreme salinity affected areas. But these RO plants fail to attract poor users to purchase water at a high price (0.5-

[74] Karim et. al., 2016

1.0 per litre) and hence these are not operated at their optimal capacity. There is 1 MAR in Tildanga union, which was installed by DPHE and is operating on pilot basis which covers 60 households (0.16%).
All the above technological options provide drinking water supply to 6,536 households and the supply coverage is 18.78%. Still there is supply gap of 81.22% in Dacope upazila.

Existing water supply technologies, coverage and supply gap of Dacope Upazila is shown in Table 27.

Table 27: Existing water supply technologies, coverage and supply gap of Dacope Upazila

Union	Total number of ward	Total Number of village	Total Number of HH	Existing Household based drinking water technology					Existing Community based drinking water technology																					Total HH covered (HH & Community)	Coverage (%)	Uncovered HH	Supply gap (%)
				DHTW		RWH		Total	Deep set Hand Tube well (DHTW)			Pond Sand Filter (PSF)			Rain Water Harvesting (RWH)			Reverse Osmosis (RO)			Piped Water Supply (PWS)			Others (MAR)			Total P options	Total P options	Total HH covered				
				Functional	Potential	Functional	Potential		Functional	Potential	HH covered	Functional	Potential	HH covered	Functional	Potential	HH covered	Functional	Potential	HH covered	Functional	Potential	HH covered	Functional	Potential	HH covered							
Sadar	9	12	1943	1	0	165	0	166	0	0	0	5	14	180	0	0	0	0	0	0	1	0	50	0	0	0	6	14	230	396	20.38	1547	79.62
Bajua	9	20	4103	0	0	37	0	37	1	0	60	10	13	510	12	0	48	0	0	0	1	0	100	0	0	0	24	13	718	755	18.40	3348	81.60
Bani Shanta	9	15	4102	0	0	291	0	291	2	0	50	8	12	285	5	0	25	0	0	0	0	1	50	0	0	0	15	13	410	701	17.09	3401	82.91
Sutarkhali	9	13	3868	0	0	76	0	76	0	0	0	21	18	700	3	0	12	0	0	0	0	0	0	0	0	0	24	18	712	788	20.37	3080	79.63
Pankhali	9	11	4400	1	0	50	0	51	0	0	0	6	0	310	2	0	10	0	0	0	0	0	0	0	0	0	8	0	320	371	8.43	4029	91.57
Tildanga	9	12	4722	0	0	695	0	695	28	0	414	1	7	38	1	0	10	0	0	0	0	0	0	1	0	60	31	7	522	1217	25.77	3505	74.23
Kamarkhol	9	19	3329	0	0	63	0	63	0	0	0	13	2	580	5	0	20	2	0	150	0	0	0	0	0	0	20	2	750	813	24.42	2516	75.58
Laudubi	9	34	6372	0	0	70	0	70	0	0	0	9	2	304	16	0	73	0	0	0	0	0	0	0	0	0	25	2	377	447	7.02	5925	92.98
Kailashganj	9	13	3868	0	0	76	0	76	0	0	0	21	18	960	3	0	12	0	0	0	0	0	0	0	0	0	24	18	972	1048	27.09	2820	72.91
Total (Dacope)	81	149	36707	2	0	1523	0	1525	31	0	524	94	86	3867	47	0	210	2	0	150	2	1	200	1	0	60	177	87	5011	6536	18.78	30171	81.22

8.4.3 Proposed water solutions

The proposed water technologies are given in Table 28.

Table 28: Proposed water technologies in Dacope Upazila

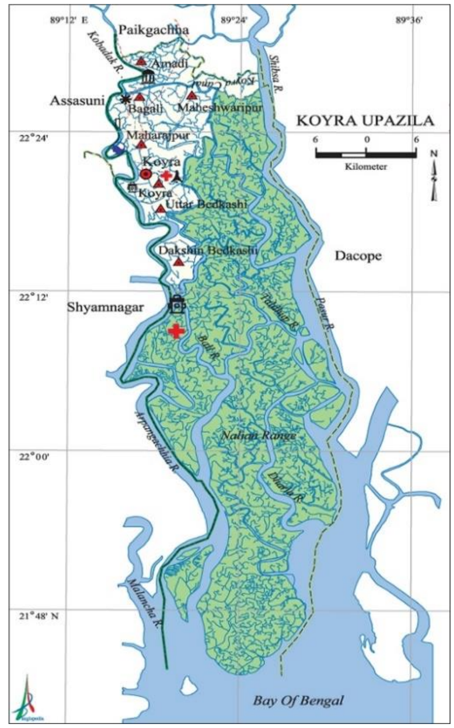
Union	Ward No.	Number of HH	# of HH with existing functioning safely managed water supplies	Target Households (50% of HH without safely managed water supplies)	Proposed Technology						
					HH based RWHS	Community based RWHS			Institution based RWHS		PSF
						in existing buildings		in new locations			
						Medium Tanks (25 HHs)	Large Tanks (50 HHs)	Large Tanks (50 HHs)	Medium Tanks (25 HHs)	Large Tanks (50 HHs)	
Dacope	1	365	49	158	31						1
Dacope	2	250	18	116	23						1
Dacope	6	300	70	115	23						1
		915	137	389	77	0	0	0	0	0	3
Bajua	8	410	162	124	74			-		1	
Bajua	9	405	74	166	33					1	1
		815	236	290	107	0	0	0	0	2	1
Banishanta	2	456	74	191	38				1	1	1
Banishanta	8	418	80	169	19			-		3	
		874	154	360	57	0	0	0	1	4	1
Sutarkhali	1	644	129	258	33			-	1		1
Sutarkhali	2	515	84	216	16			-			1
Sutarkhali	4	345	91	127	25						1
		1,504	304	600	73	-	-	-	1	-	3
Pankhali	4	645	7	319	69			3		2	
		645	7	319	69	-	-	3	-	2	-

Union	Ward No.	Number of HH	# of HH with existing functioning safely managed water supplies	Target Households (50% of HH without safely managed water supplies)	Proposed Technology						
					HH based RWHS	Community based RWHS			Institution based RWHS		PSF
						in existing buildings		in new locations			
						Medium Tanks (25 HHs)	Large Tanks (50 HHs)	Large Tanks (50 HHs)	Medium Tanks (25 HHs)	Large Tanks (50 HHs)	
Tildanga	1	800	110	345	70	1		5			
Tildanga	3	600	170	215	65			2		1	
		1,400	280	560	135	1	-	7	-	1	-
Kamarkhola	6	600	57	272	72			2		2	
Kamarkhola	8	334	20	157	57			2			
Kamarkhola	9	405	50	178	35					1	1
		1,339	127	606	164	-	-	4	-	3	1
Laudubi	1	261	88	87	37			-		1	
Laudubi	3	225	60	83	33			1			
Laudubi	9	176	16	80	30			-		1	
		662	164	249	99	-	-	1	-	2	-
Kailashganj	5	417	127	145	20			-	1	2	
Kailashganj	6	503	82	211	42	1				1	1
Kailashganj	7	317	55	131	26						1
		1,237	264	487	88	1	-	-	1	3	2
Total		**9,391**	**1,673**	**3,859**	**869**	**2**	**-**	**15**	**3**	**17**	**11**

8.5 Upazila: Koyra

8.5.1 Background (geography, socio-economic)

Koyra Upazila (Khulna district) area 1775.41 sq km, located in between 22°12' and 22°31' north latitudes and in between 89°15' and 89°26' east longitudes. It is bounded by Paikgacha upazila on the north, the Bay of Bengal and Sundarbans on the south, Dacope upazila on the east, Assasuni and Shyamnagar upazila on the west.



Total population of this upazila is **343,701** where female is **167,715** and male is **175,986**. Koyra upazila surrounded by the Kapataksa, Sakabariya and Koyra rivers.

Water bodies Main rivers: Dharla, Pasur, Arpangachhia, Taldhup, Malancha, kobadak, ball; Koyra canal is notable.

Main sources of income Agriculture 66.64%, non-agricultural laborer 7.12%, industry 0.51%, commerce 12.66%, transport and communication 1.85%, service 3.54%, construction 1.31%, religious service 0.31%, rent and remittance 0.09% and others 5.97%.

Table 29: Demographic information of Koyra Upazila

Union	Total Number of village	Total No. of Households	Population		
			Female	Male	Total
Amadi	30	10,410	24,022	28,400	52,422
Maheshareepur	23	10,194	30,900	36,100	67,000
Bagali	28	13,118	30,188	30,788	60,976
Sadar	13	10,219	26,936	25,870	52,806
Maharajpur	24	9,888	28,570	27,920	56,490
Uttar Bedkashi	24	4,277	12,010	12,174	24,184
Dakhsin Bedkashi	17	5,769	15,089	14,734	29,823
7	159	63,875	167,715	175,986	343,701

8.5.2 Drinking Water Sources, Supply, and Access

From analyses on the information collected during PRA process and expert judgment by the technical team, current drinking water supply options of Koyra upazila were identified. There were three major sources of drinking water in the Union which are rainwater, groundwater from a shallow aquifer, and pond water.

Each existing drinking water source was classified as either functioning or potential. The definitions for these are as follows:

- Functioning
- Potential

Among these three sources, rainwater is conventionally harvested by the households for drinking purpose during the rainy season. Since rainfall in Bangladesh is abundant, local people can use rainwater for drinking and cooking purposes during the rainy season. They use the rooftop as catchment and store rainwater in reservoirs. Rainwater is popular among women as they can store water in their houses and do not need to go outside for collection. However, although rainwater quality is good, stored rainwater often gets contaminated due to poor maintenance of catchment and unhygienic storage system. It was reported during the PRA session that people in this area do not use any disinfection system. As previous studies suggest that rainwater stored in rural areas often contain bacteriological contamination[75], this is a limitation of this technology if used without any disinfection system as it may have negative health impacts. In addition, absence of rainfall during winter and early part of the pre-monsoon makes storing water for the dry season difficult for people of Koyra Upazila. Most of the households do not have large rainwater reservoirs, as these are too expensive for them. Therefore, rainwater being currently used at household level during rainy season provides a dependable solution for the whole year if rainwater tanks with large storage capacity can be made available to local people. In addition, awareness raising on safe use of rainwater and maintenance of the system will help ensuring water safety at the user's end. There are a total 440 household based functional RWHS and 197 community based functional RWHS in Koyra Upazila which covers 637 households (1.00%).

In all 7 union, there is a source of fresh groundwater that provides drinking water to the community by extraction through deep hand tubewell (DHTW). A total of 121 household based functional DHTWS and 507 community based functional DHTW in Koyra Upazila covering 6843 households (10.71%). These DHTW provide water round the water and reduces the collection time and effort of the woman substantially in those 7 unions. However, salinity intrusion in the deep layer is perceived to be the main threat of climate change in these areas. There are 1 piped water supply scheme based on ground supply in 1 union of Koyra Upazila, which provide drinking water supply to 200 households (0.31%). Piped water supply provides water supply at the door step of the households and substantially reduces collection effort of the women. But water quality of these piped water schemes is not up to the mark and water supply is not also regular.

In areas where fresh water ponds are available, people depend on pond water, especially during dry season when rainwater is not available. But fresh water ponds are very scarce in Koyra Union and people, especially women, are seen to collect pond water from a distance of 2 to 3 kilometers. Due to a lack of adequate maintenance, these ponds are found vulnerable to pollution. But absence of any other sources makes a large number of households dependent on this unsafe source for drinking water. In some households, alum is used in pond water which fastens precipitation of suspended particles, though it does not effectively remove bacteriological contamination from water. For treatment of pond water, pond sand filters (PSFs) are often proposed in coastal areas. There are 21 functional pond sand filters (PSF) based on these fresh ponds, which provides drinking water to 735 households (1.15%) of Koyra. But it was observed in the study area that due to operational and maintenance difficulties (cleaning of filter beds, lifting of water into the filter chambers, lack of repair/maintenance funds, etc.) these PSFs do not sustain. It was also reported by the local communities in Koyra that a large number of PSFs installed in the Union are currently non-functional (40%).

[75] Karim et. al., 2016

There are 2 Reverse Osmosis (RO) plants in 2 unions of Koyra upazila which provides water supply to 110 households (0.17%). These RO plants are operated by different NGOs on business model in extreme salinity affected areas. But these RO plants fail to attract poor users to purchase water at a high price (0.5-1.0 per litre) and hence these are not operated at their optimal capacity.

All the above technological options provide drinking water supply to 8,525 households and the supply coverage is 17%. Still there is supply gap of 83% in Koyra upazila

Table 30: Existing water supply technologies, coverage and supply gaps of Koyra Upazila

Union	Total number of ward	Total Number of village	Total Number of HH	Existing Household based drinking water technology					Existing Community based drinking water technology																					Total HH covered (HH & Community)	Coverage (%)	Uncovered HH	Supply gap (%)
				DHTW		RWH		Total	Deep set Hand Tube well (DHTW)			Pond Sand Filter (PSF)			Rain Water Harvesting (RWH)			Reverse Osmosis (RO)			Piped Water Supply (PWS)			Others (MAR)			Total P options	Total P options	Total HH covered				
				Functional	Potential	Functional	Potential		Functional	Potential	HH covered	Functional	Potential	HH covered	Functional	Potential	HH covered	Functional	Potential	HH covered	Functional	Potential	HH covered	Functional	Potential	HH covered							
Amadi	9	30	10,410	-	-	51	-	51	1	-	20	12	6	370	-	-	-	-	-	-	-	-	-	-	-	-	13	6	390	441	4	9,969	96
Maheswaripur	9	23	10,194	-	-	170	-	170	3	-	90	1	3	50	-	-	-	-	-	-	-	-	-	-	-	-	4	3	140	310	3	9,884	97
Bagali	9	28	13,118	-	-	73	-	73	8	-	176	1	2	50	1	-	4	1	-	70	-	-	-	-	-	-	11	2	300	373	3	12,745	97
Sadar	9	13	10,219	9	-	15	-	24	117	15	2,030	4	-	190	27	-	108	1	-	40	-	-	-	-	-	-	149	15	2,368	2,392	23	7,827	77
Maharajpur	9	24	9,888	50	-	88	-	138	59	7	693	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	59	9	693	831	8	9,057	92
Uttar Bedkashi	9	24	4,277	37	1	43	-	80	68	3	890	3	1	75	16	-	85	-	-	-	1	-	200	-	-	-	88	4	1,250	1,330	31	2,947	69
Dakhsin Bedkashi	9	17	5,769	25	-	-	-	25	251	14	2,823	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	251	14	2,823	2,848	49	2,921	51
Total (Koyra)	63	159	63,875	121	1	440	-	561	507	39	6,722	21	14	735	44	-	197	2	-	110	1	-	200	-	-	-	575	53	7,964	8,525	17	55,350	83

8.5.3 Proposed water solutions

The proposed water technologies, quantity and cost for proposed technologies are given in Table 31.

Table 31: Proposed water technologies in Koyra Upazila

Union	Ward No.	Number of HH	# of HH with existing functioning safely managed water supplies	Target Households (50% of HH without safely managed water supplies)	Proposed Technology						
					HH based RWHS	Community based RWHS			Institution based RWHS		PSF
						in existing buildings		in new locations			
						Medium Tanks (25 HHs)	Large Tanks (50 HHs)	Large Tanks (50 HHs)	Medium Tanks (25 HHs)	Large Tanks (50 HHs)	
Amadi	6	825	0	413	163			5			
Amadi	7	1,100	20	540	265			5	1		
		1,925	20	953	428	-	-	10	1	-	-
Maheswaripur	1	900	30	435	110		2	2	1	2	
Maheswaripur	8	1,300	28	636	186			5		4	
Maheswaripur	9	1,400	30	685	385			5		1	
		3,600	88	1,756	681	-	2	12	1	7	-
Bagali	2	2,500	138	1,181	881	1		5	1		
		2,500	138	1,181	881	1	-	5	1	-	-
Koyra Sadar	2	1,260	285	488	113	3	1	4		1	
Koyra Sadar	4	1,425	540	443	93		1	3		3	
		2,685	825	930	205	3	2	7	-	4	-
Maharajpur	2	1,450	164	643	168	2	1	2	1	1	1
Maharajpur	7	865	211	327	77		2	1		2	
Maharajpur	**8**	**2,045**	120	963	663			5		1	
		4,360	495	1,933	908	2	3	8	1	4	1
Uttar Bedkashi	1	700	10	345	95			5			
Uttar Bedkashi	7	355	294	31	31			-			
Uttar Bedkashi	9	350	15	168	68			1		1	
		1,405	319	543	193	-	-	6	-	1	-
Dakshin Bedkashi	3	603	10	297	97			4			
Dakshin Bedkashi	**8**	**425**	200	113	63			0		1	
		1,028	210	409	159	-	-	4	-	1	-
Total		**17,503**	**2,095**	**7,704**	**3,454**	**6**	**7**	**52**	**4**	**17**	**1**

9. Site/Beneficiary Selection, Committee Formation, Implementation and Operation and Maintenance

9.1 Site/Beneficiary Selection

The targeted households in 39 Unions of 5 Upazilas under Khulna and Satkhira districts will be provided with safe water options through the following systems:

1. Household based rainwater harvesting systems
2. Community/Institution based rainwater harvesting systems
3. Community based pond water treatment system (Sky-hydrant)

The beneficiaries for community/institution based systems will be selected by the implementing organizations. Since safe distance for water collection has been assumed as 0.5 Km for the users, the location of households of beneficiaries of community/institution based systems designed for 25 (medium size rainwater tank), 50 (large size rainwater tank) or 200 households (pond water treatment system) will be within 0.5 Km of water point. Households that would not be covered by community/institution based systems will be provided with household rainwater tanks. Priority for selection of beneficiaries for household based systems will be given to people with disability, ethnic minorities in the area who might not have access to the community water options, and to people who lives outside 0.5 Km radius of the water points.

The selection of sites for community/institution based systems will follow the proposed number of systems for each ward. The total number of proposed medium/large tanks at existing community buildings or institutional buildings is provided in the report (see annex: Union profiles). Site visit has to be carried out to these existing buildings to check whether the buildings are suitable for installation of rainwater tanks. Moreover, few new large size tanks are proposed in new locations where a new roof will also be installed for harvesting rainwater. The ponds for installing Sky-hydrants will be selected after testing water quality of pond water in laboratory.

The selection of sites and beneficiary households will be carried out by the implementing organization, which will be supported by local government officials (Union Council Chairman, Members, etc.) and Department of Public Health Engineering (DPHE).

9.2 Formation of Committees

In order to ensure smooth implementation of the project, participation of user groups as well as officials from local government and DPHE would be critical. Two types of groups/committees will be formed at the beginning of the project:

1. User group formation

2. Water management committee formation

9.2.1 User group formation

The user group will be formed comprising of one member (women will get priority) from each of the targeted households. The group will be formed in clusters based on their proximity and type of water options they will receive. The groups will gather in every three months to discuss about supply of water in their households and any water related issues (e.g., water quality, availability of water year-round, hygiene practice, etc.). The implementing NGO will facilitate the user group meetings and will be responsible for providing support to address the problems discussed in user group meetings.

9.2.2 Water management committee formation

In each of the targeted wards in 39 Unions, one water management committee will be formed whose main responsibility will be to look after the water options provided to ensure proper management of the systems. The management committees will be formed prior to installation and commissioning of water options. The members of the management committees will comprise of:

- Local government representatives (Ward Councilor)
- Representative from DPHE
- One representative from each of the community/institution based system (rainwater tanks/Sky-hydrants)
- One representative from each of the user group
- Local expert(s) with knowledge of water management

The responsibilities of the water management committees in each of the targeted wards include:

1. Adaptive water distribution planning
2. Planning of adaptive operation and maintenance of water options, including water quality monitoring
3. Development of fee-based model and financial management system
4. Addressing the problems/issues raised by user groups
5. Monitoring of caretakers' performance to operate the community/institution based water options
6. Contacting the suppliers and taking necessary steps for system troubleshooting, any repair or maintenance works
7. Re-organization of the committee as per requirement

The water management committees will be responsible for arranging the quarterly meetings once in each quarter of the year after its formation.

9.3 Implementation Modalities

The proposed intervention under this climate resilience program targeting increase of safe drinking water coverage with the proposed water technologies is expected to be implemented by DPHE, the designated government agency in partnership with the national and local NGOs and in collaboration with the Local Government (UP). Under this modality, UP will provide support for site selection for installation of the proposed community based technological options and selection of poor and extreme poor households for distribution of the household based RWH units. The NGOs are expected to play role in community mobilisation and demand creation for improved water supply services, identify potential WASH entrepreneurs and build their capacity to take up operation and maintenance of the community options having high potential to run on business model.

9.4 Exit strategy

The proposed options are expected to be implemented by national government agency (DPHE) in collaboration with the local government (UP) and private sector with direct involvement of community or institution based committees. The household based RWH option will be implemented in collaboration with the UP. UP will take initiative to identify the extreme poor, poor, women headed households, who deserve to have this facility in their houses. The community options like RWH and Sky-hydrant will be implemented either directly by the implementing agency with involvement of CBO committee formed by UP. The institution based RWH will be implemented in collaboration with UP with direct involvement of institution based management committee. After successful implementation of the hardware intervention, the implementing agency will hand over the installed facilities to the UP, respective committees and household and will withdraw from the intervention process. However, in this regard, the following exit strategies will be followed:

- Develop technological option based O&M guideline including WSP for the households, committees and private entrepreneurs and provide necessary training and orientation to the UPs, committee members, plant operators and caretakers;
- Provide on-the-job support to the above committees, private entrepreneurs and plant operators enabling them for ensuring smooth O&M of the options;
- Provide support for developing local level functional mechanism for O&M in each option including O&M fund development;
- Establish link between the committee/ private entrepreneur and technical organisation/private O&M service providers for ensuring continued technical back-up support;

Define ownership of the community and institution based installed facilities and hand over facilities to the owner specifying roles and responsibilities of the facility owner to keep the facilities operational and providing sustainable drinking water supply services to the community.

9.5 Operation and Maintenance of the Water Technologies

9.5.1 Household Rainwater Harvesting Systems

The households will be responsible for all kinds of maintenance of their rainwater harvesting systems. The major maintenance steps are:

- Cleaning of catchment, gutter and pipes at regular interval during rainy season (at least once in a month) and especially once before arrival of rain (February/March)
- Cleaning of rainwater reservoir tank and the water filter at least twice a year
- Placing the rainwater reservoir on a raised platform to maintain hygienic environment around the system
- Keeping the first flush valve open before rainfall and closing the valve after first 2.5 mm of rainfall
- It is highly recommended to boil water or to use any disinfection system before drinking

9.5.2 Community/Institution Based Rainwater Harvesting System

One caretaker will be trained by experts on operational maintenance of the system, who will be responsible for maintenance of the rainwater harvesting system. The major operation and maintenance steps are:

- Monitoring of distribution of water among the households where each household will get water equally
- Cleaning of catchment, gutter and pipes at regular interval during rainy season (at least once in a month) and especially once before arrival of rain (February/March)
- Cleaning of rainwater reservoir tank and water filter at least twice a year
- Maintaining hygienic environment around the system
- Keeping the first flush valve open before rainfall and closing the valve after first 2.5 mm of rainfall
- It is highly recommended to boil water or to use any disinfection system before drinking

9.5.3 Sky-hydrant System

To operate the Sky-hydrant system, a trained caretaker with good knowledge of the system will be required. Therefore, one caretaker will be trained on operational maintenance of the system at each site, who will be responsible for maintenance of the system. The caretaker will also be responsible for regular communication with the suppliers of the materials that will be needed on a regular basis to keep the system functional. Few major operation and maintenance issues for this system are:

- The embankment height should be designed above the water level (predicted by local people) during tidal surges and this height should be maintained
- All types of washing/cleaning activities should be prohibited in the ponds
- Fencing around the ponds should be maintained round the year to prevent intrusion of animals/livestock into the ponds
- Pond should be cleaned at least once a year to remove plants and other harmful species from the ponds

- Any practice of saline water based aquaculture (e.g., shrimp farming) around the pond area should be prohibited
- In this system, raw water from sweet pond is sent to raw water tank of SPSF by solar pump. The pump has a sensor that will start the pump once water inside the raw water tank goes below a certain level. For rainy days and emergency situations, when the pump cannot be run, a hand pump is provided with the system.
- The caretaker will monitor equal distribution of water among the households where each person in a household will get water equally

9.6 Training for Users and Caretakers

The caretakers of community water systems and users of the water technologies will be trained on proper way of operation and management of the systems. The user training will be conducted once every year for the users of household based systems and the user groups of community systems. The training will focus on hygienic practice of water storage, collection, transportation and use. The water quality management of drinking water will be discussed in the training sessions.

The caretaker training will be done once every year where the caretakers of different community systems (rainwater harvesting and pond water treatment) will be trained on operation, maintenance and management of the water systems. For the caretakers of Sky-hydrant systems, the suppliers will train the caretakers. The caretakers will also be trained on water quality testing using the toolkits. One set of water quality test kits will be provided to each of the Unions which can be used to test pH, Turbidity, Total Dissolved Solids, Electrical Conductivity and Fecal Coliform. The caretakers will be responsible for performing water quality tests of their systems.

9.7 Water Quality Management

Although filters will be provided to all the rainwater systems and the Sky-hydrant system will have an additional disinfection system, there is possibility of water getting contaminated during transportation of water and storage in house. Therefore, in the training sessions, water quality management of stored rainwater and importance of disinfection before drinking water will be discussed. Two disinfection techniques could be given priority considering the local context: boiling and solar disinfection systems. However, during the training sessions, the trainers will discuss other methods of disinfection and will encourage the users to disinfect water before drinking.

9.8 Management /User Committees in Operation and Maintenance: WaterAid Experience and Findings

9.8.1 The Status Quo of Community Involvement

Community involvement for the water point is a two-tier formation. Strategic decisions regarding the water point is taken by the WDMC (ward development management committee) and regular maintenance is supervised by the MC (management committee).

	WDMC	MC
No. of members	20-25 people	2-5 people
Responsibilities	Strategic decisions regarding the water point such as need assessment, setting up the facility, any modifications (such as digging the pond deeper for PSF, procuring new storage tanks for RWHS etc.)	Day to day activities regarding the water point such as the looking after the maintenance and regular operations of the water point.

Furthermore, the committee tasked with maintaining the sites are very important factor behind user satisfaction and the overall performance of the sites. In 2016, WaterAid conducted a study to analyze the sustainability of the water intervention especially built in Satkhira and Khulan. The survey result showed that 66% of the committees are active while 21% said are currently inactive and 13% are sporadic.

The survey also showed that the activity of the committee are an important factor behind the performance of the sites. In sites where the committee was active, 88% of users who used the sites were satisfied with the water quality, signaling the fact that the committee was doing its job of maintaining the sites. On the other hand, in sites where the committee was not active, 70% of users were satisfied with the water quality.

In sites where the committee was not active, a majority of the population felt more initiatives had to be taken to involve the community further. It also reflects that there are needs for a completely new committee through fair elections. This would better ensure proper maintenance of sites when required and improve people's access to safe drinking water in the target areas. In sites where the committee was active, 91% of the surveyed population felt that it was helpful in the administration and water collection of the respective sites. Additionally, many users were willing to pay for maintenance of the sites if they were satisfied with the water quality.

9.8.2 Management Committee Performance

Local management committees can play pivotal roles for effectively managing each water units. Each committee is overseen by Ward Development Management Committee (WDMC) consisting of elected representatives, local respected elders, caretakers and representatives of different government entities. The WDMC makes periodic strategic decisions pertaining to different development aspects of the area. As an extension, WDMC is responsible for overseeing the functioning of the WaterAid funded water units.

Over the last five years, the role of WDMC has evolved from looking into disaster management issues, to effectively managing different development challenges in local areas. The eventual goal with the committee is to unify decision making process, by adopting a ‘bottom-up’ approach for solving development challenges.

Schema: The bottom-up approach adopted by the management committee

In the areas where the units are not operating, laxity in management has been identified as the predominant cause for non-functionality. In areas where the water units are not operating, the main cause identified has been the committee's failure in raising adequate funds for making repairs.

In areas where the units are performing better, management committees have played a pivotal role in ensuring proper maintenance, by regularly raising funds from local beneficiaries.

The survey result showed that the main causes for inactive committees were:

- Internal disputes
- Failure to raise funds
- Lack of initiative
- indecision and deadlocks

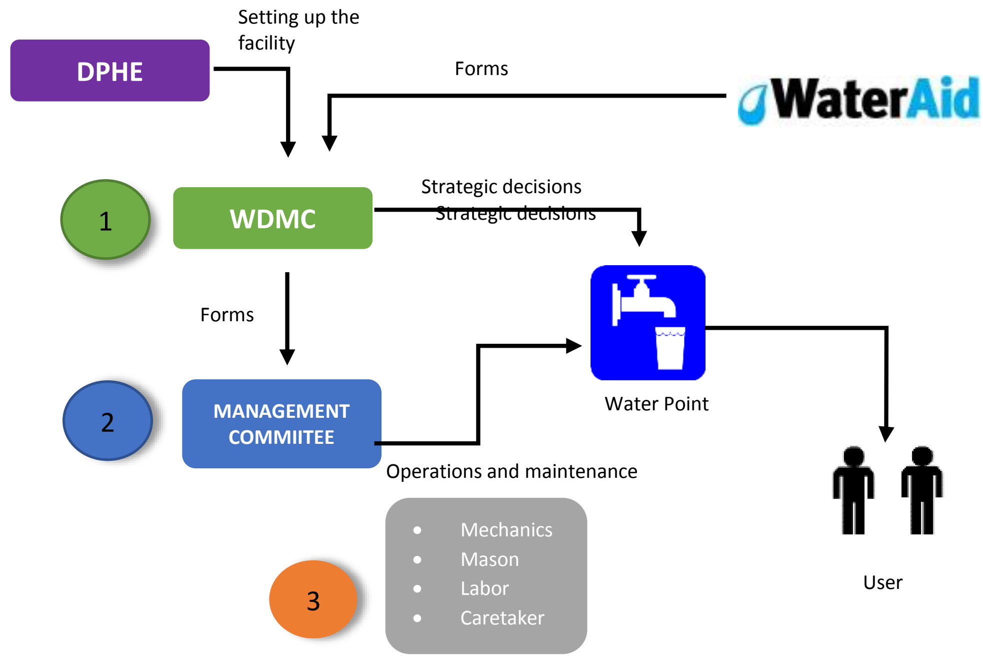
Further to that, members of management committees have identified increasing awareness among beneficiaries, lack of access to alternate drinking water sources and saline intrusion as the main reasons behind beneficiaries regularly paying for maintenance.

9.8.3 Status of External Support from Service Providers and Local Governance

Current Role of Government

Local government participation is ensured in the current format of the WDMC through incorporating the union member as president of the WDMC. The WDMC format also includes an engineer of DPHE for installation of the site and help regarding periodic repairs. The study showed that 60% of the sites did not get any help from the local government regarding maintenance and 40% of the sites received help from the local government (chairman or DPHE) such as funds for maintenance or spare filters for replacing damaged ones, giving tanks for setting up a RWHS etc.

Stakeholder Mapping in Water Supply Services



Schema: Stakeholder mapping for the water

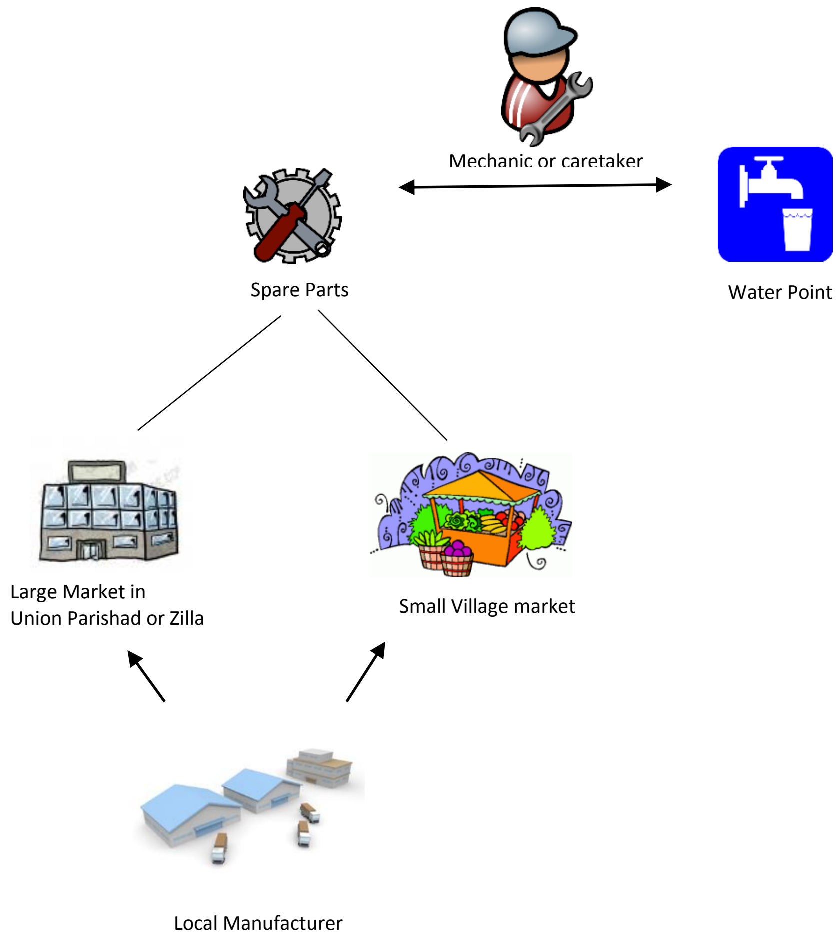
1 WaterAid sets up water points through the ward-based WDMC in each ward. DPHE helps the WDMC in installation of the water point.

2 WDMC forms the management committee which is responsible for the everyday operation and maintenance of the water point. A caretaker is selected who lives near the water point and is the head of the management committee supervising repairs and money collection needed for repairs.

3 When repairs are needed the caretaker hires a mechanic or mason or he himself may collect the spare parts and repair it.

9.8.4 Situation of Supply Chain Services for O&M of the Water Facilities

The caretaker or a hired mechanic for the site collects and replaces the spare parts for the water point. Spare parts and raw materials for the boreholes, PSF and RWHS are manufactured and available locally. For the desalination plants (reverse osmosis), two corporations supply the required parts; Prithula Foundation and Osmonic.



Schema: Value chain analysis of spare parts

According to the survey it showed that the raw materials for the boreholes, PSF and RWHS are available locally and procurement was easy but in people mostly living in remote areas deemed procurement difficult and the materials were not readily available in their immediate vicinity and that distance was a major factor in influencing the proper functioning of the sites in the respective areas. The spare parts for the desalination plant (reverse osmosis) was comparatively hard to procure. There are only 2 companies that supply spare parts (membrane filters, taps and tanks etc.) for the reverse osmosis plant- Prithula Corporation and Osmonic limited.

9.8.5 Recommendations for Sustainability

Current Technology Recommendations

Technology	Problems of Non Users	Problems of Users	Recommendation
Pond Sand Filter (PSF)	*communities who did not collect water from the sites said the pumps were not working properly, followed by communities who said they had access to alternate sources of water*	▪ *The unsatisfied users were dissatisfied with the taste and smell of water*	▪ *Management committees of PSF sites to be strengthened by improving communication and accountability as majority of the problems stemmed from it. Additionally, RWHS can be set up with the PSF facilities to augment supply*
Rainwater Harvesting System (RWHS)	▪ *Almost all the communities who didn't collect water from the sites said they did so because the taps were not functioning because of unavailability of water*	▪ *The unsatisfied users cited unavailability of water and poor quality of water (stemming from the tanks due to inability of labors to clean them) as the problem,.*	▪ *Ferrocement tanks can be setup to make it easier to clean, cheaper to build and increase capacity. However, RWH systems need to be supported by other technologies due to heavy reliance on the amount of rainfall*

10. Portfolio of Climate Resilient Water Technologies

10.1 Technical Design and Diagrams

The schematic diagrams and technical drawings of the water technologies are provided in this section.

10.1.1 Household Rainwater Harvesting Systems

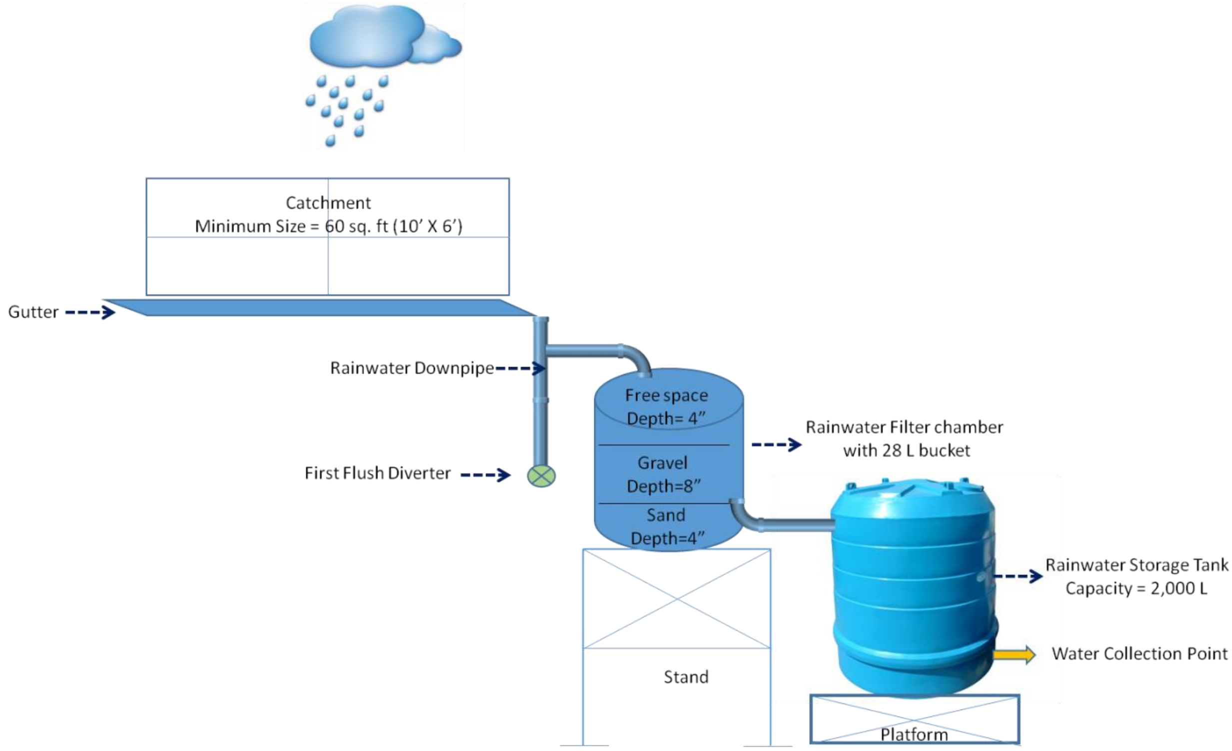


Figure 14: Schematic diagram of household rainwater harvesting system with filtration

10.1.2 Community/Institutional Rainwater Harvesting Systems (medium size tank for 25 households)

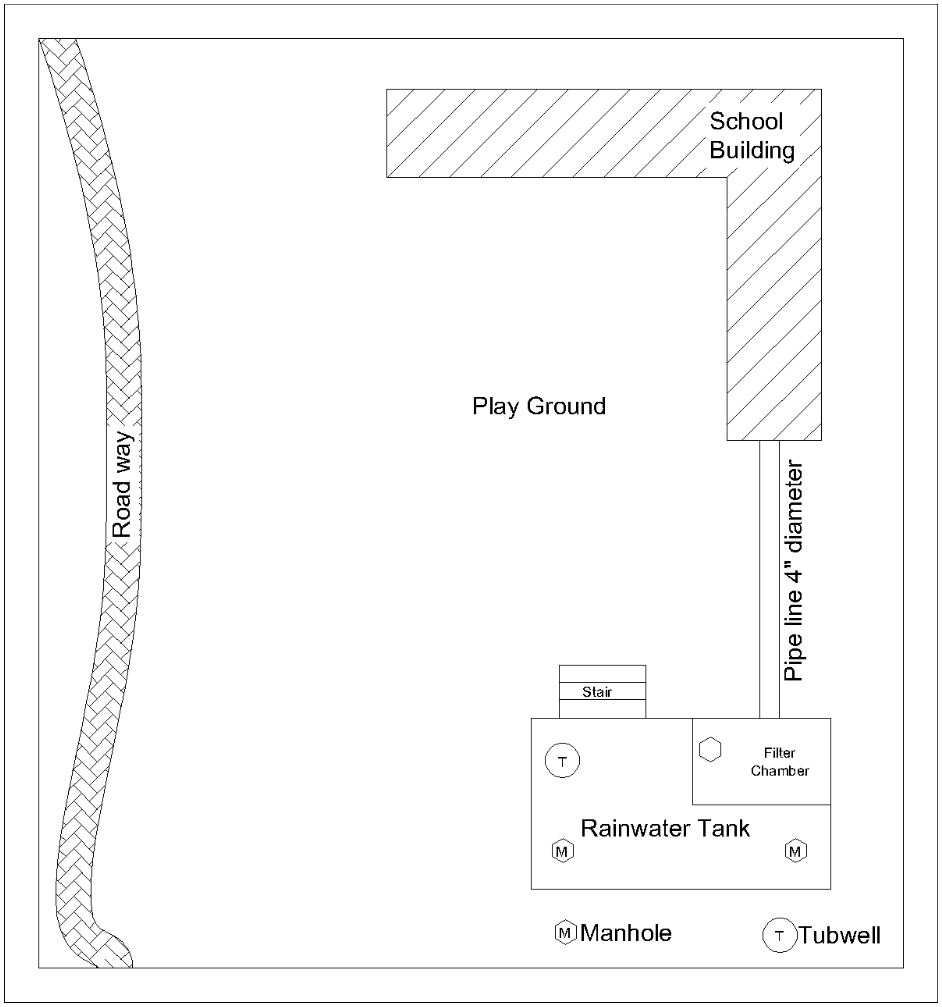


Figure 15: Layout of the system

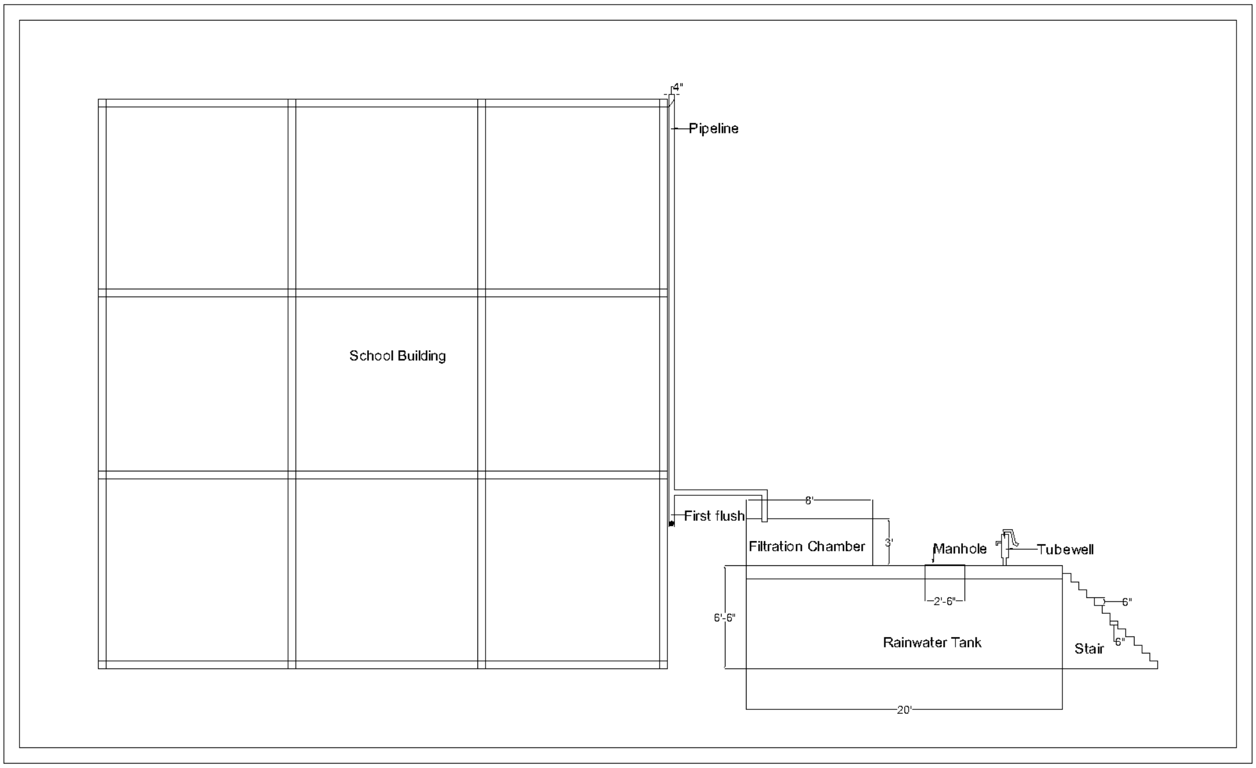


Figure 16: Side view of the system

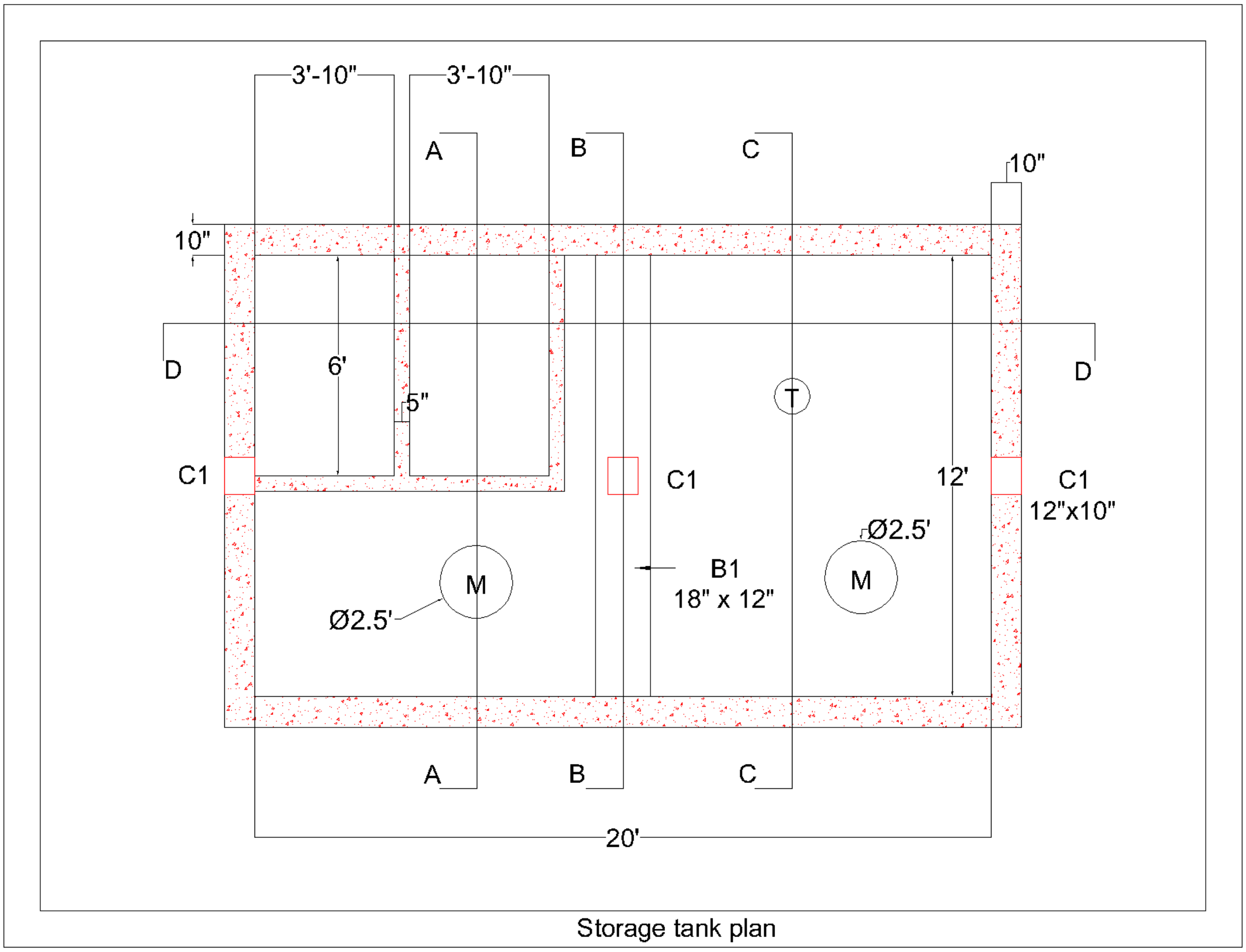


Figure 17: Storage tank plan

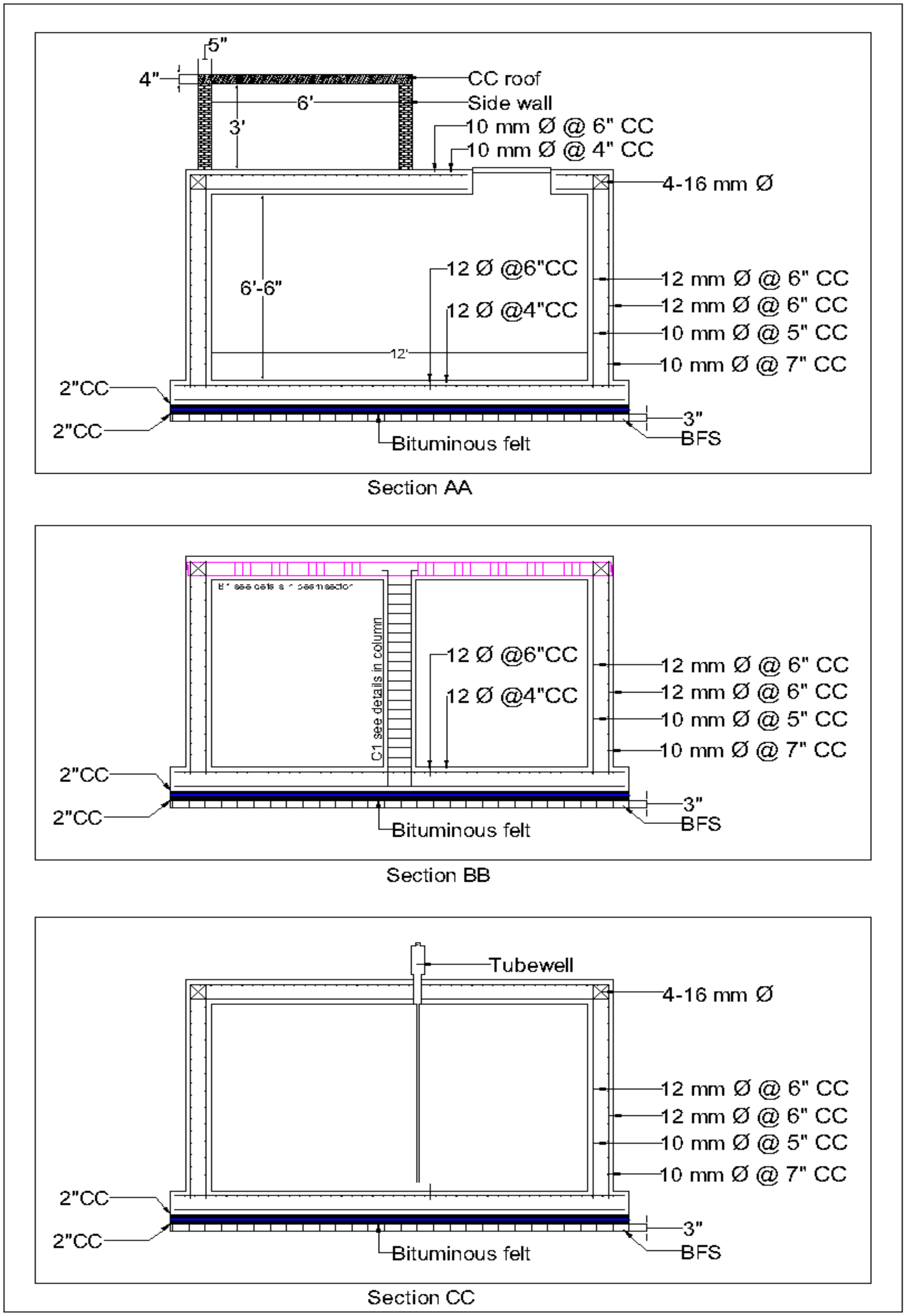


Figure 18: Cross sections of the storage tank

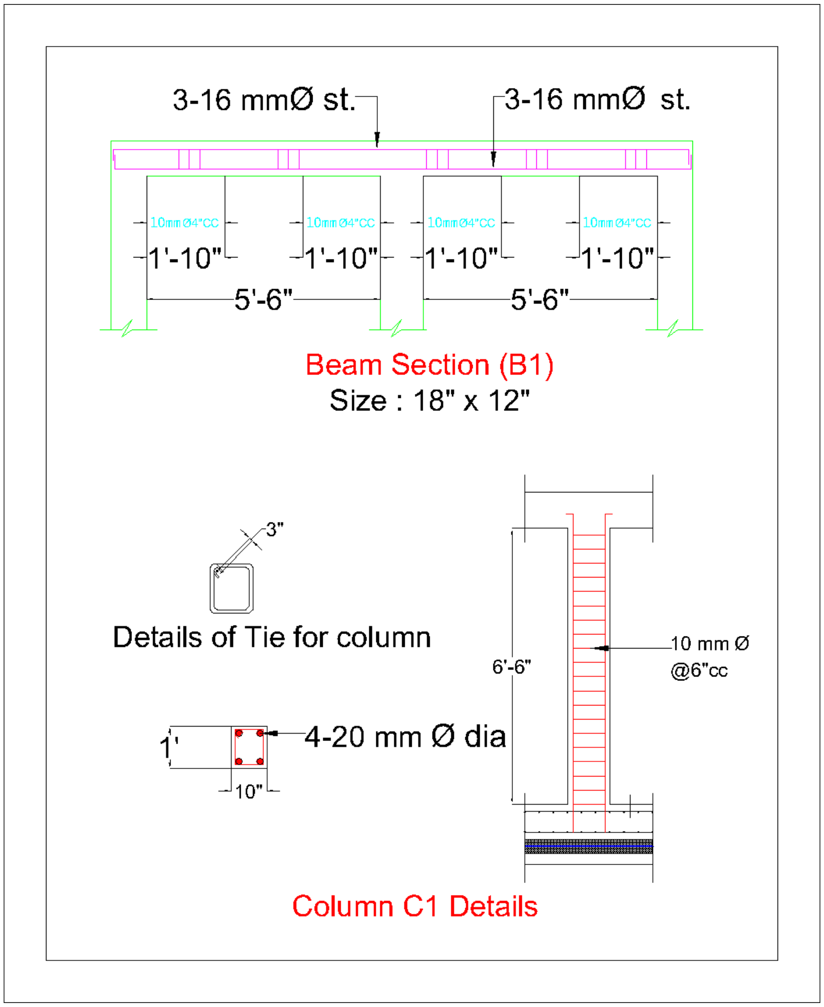


Figure 19: Beam and column sections of the storage tank

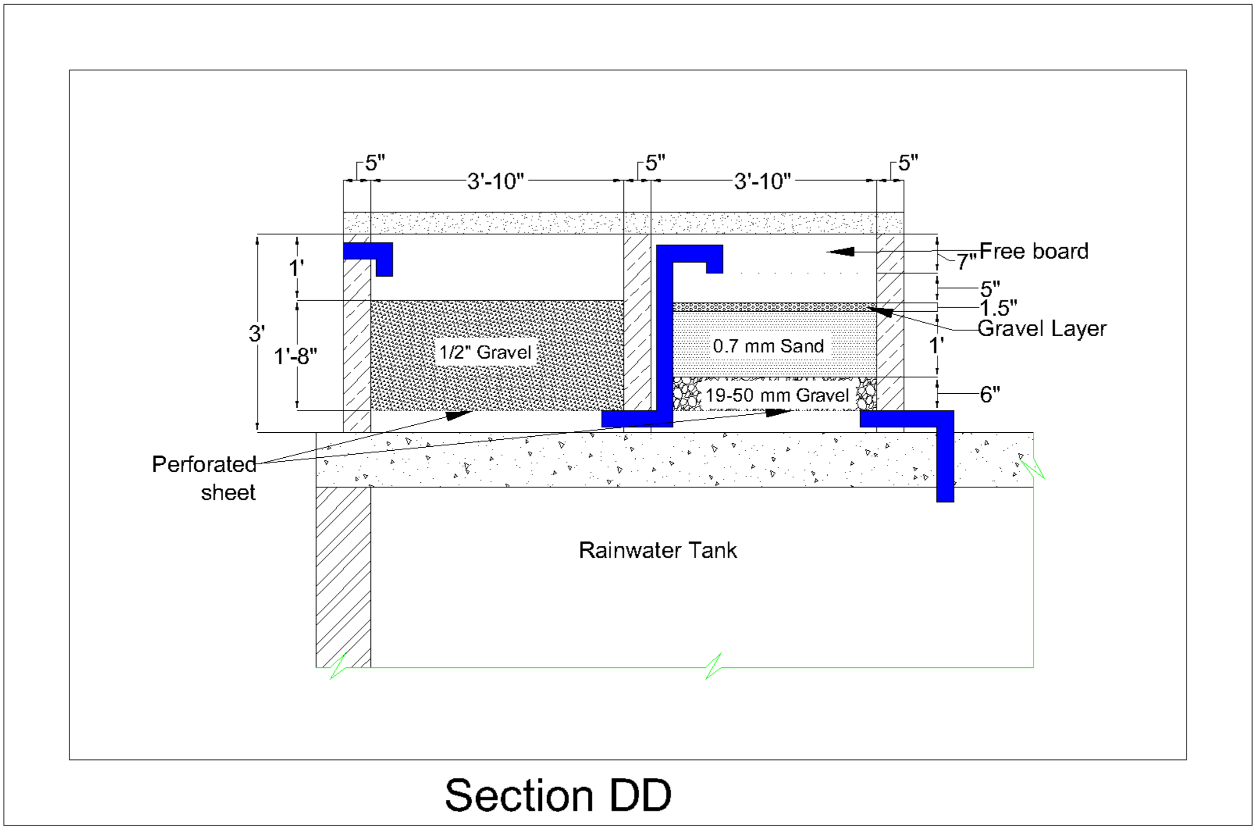


Figure 20: Filter media of the rainwater harvesting system

10.1.3 Community/Institutional Rainwater Harvesting Systems (large size tank for 50 households)

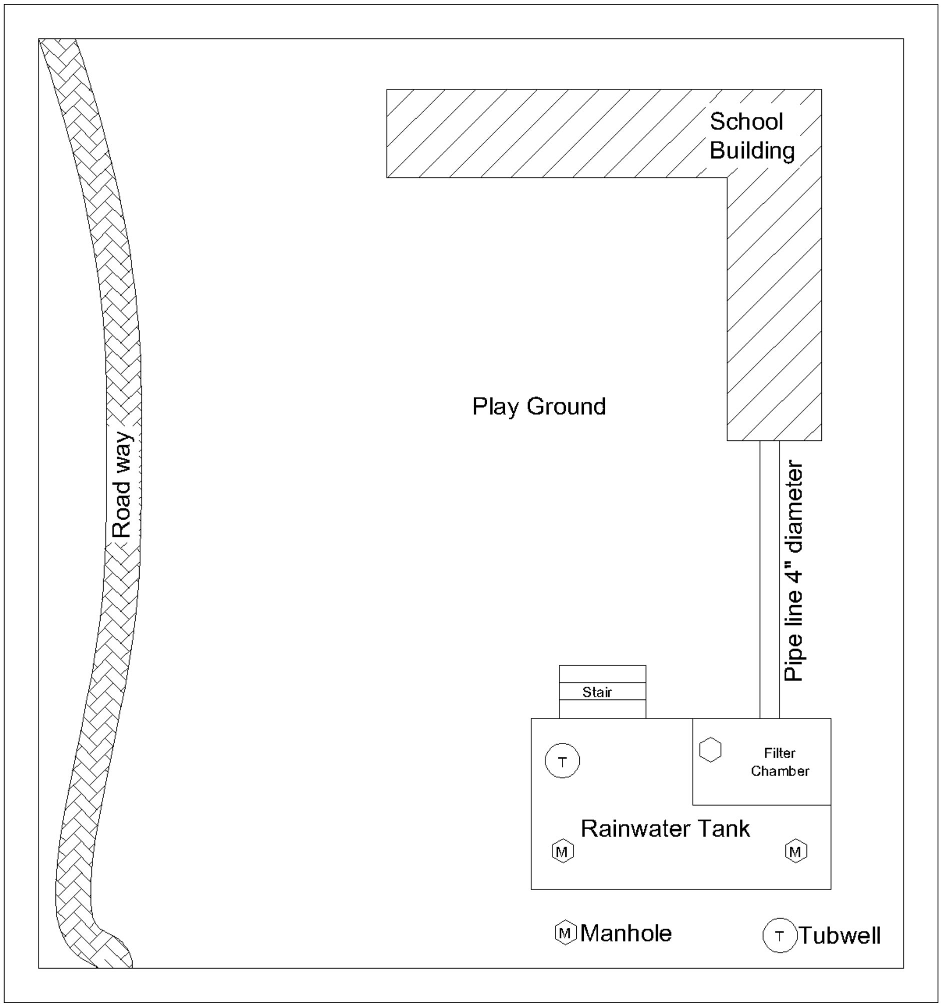


Figure 21: Layout of the system

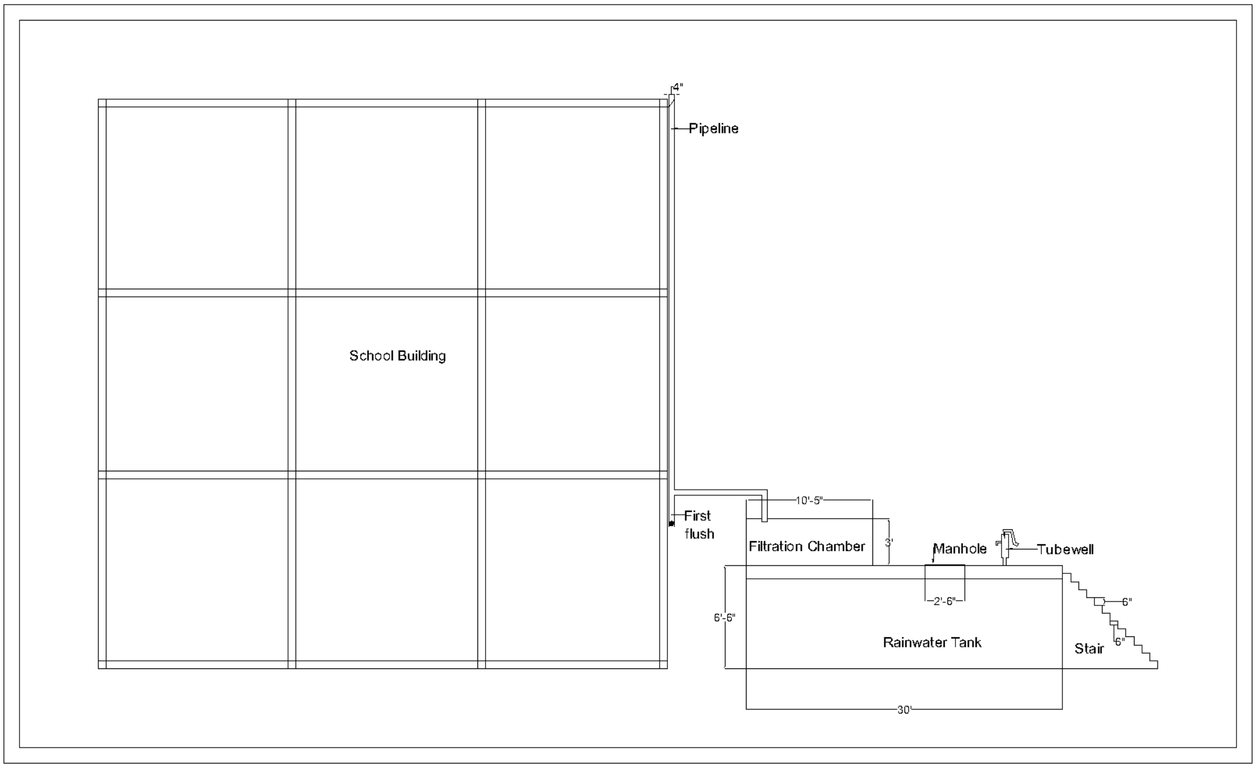


Figure 22: Side view of the system

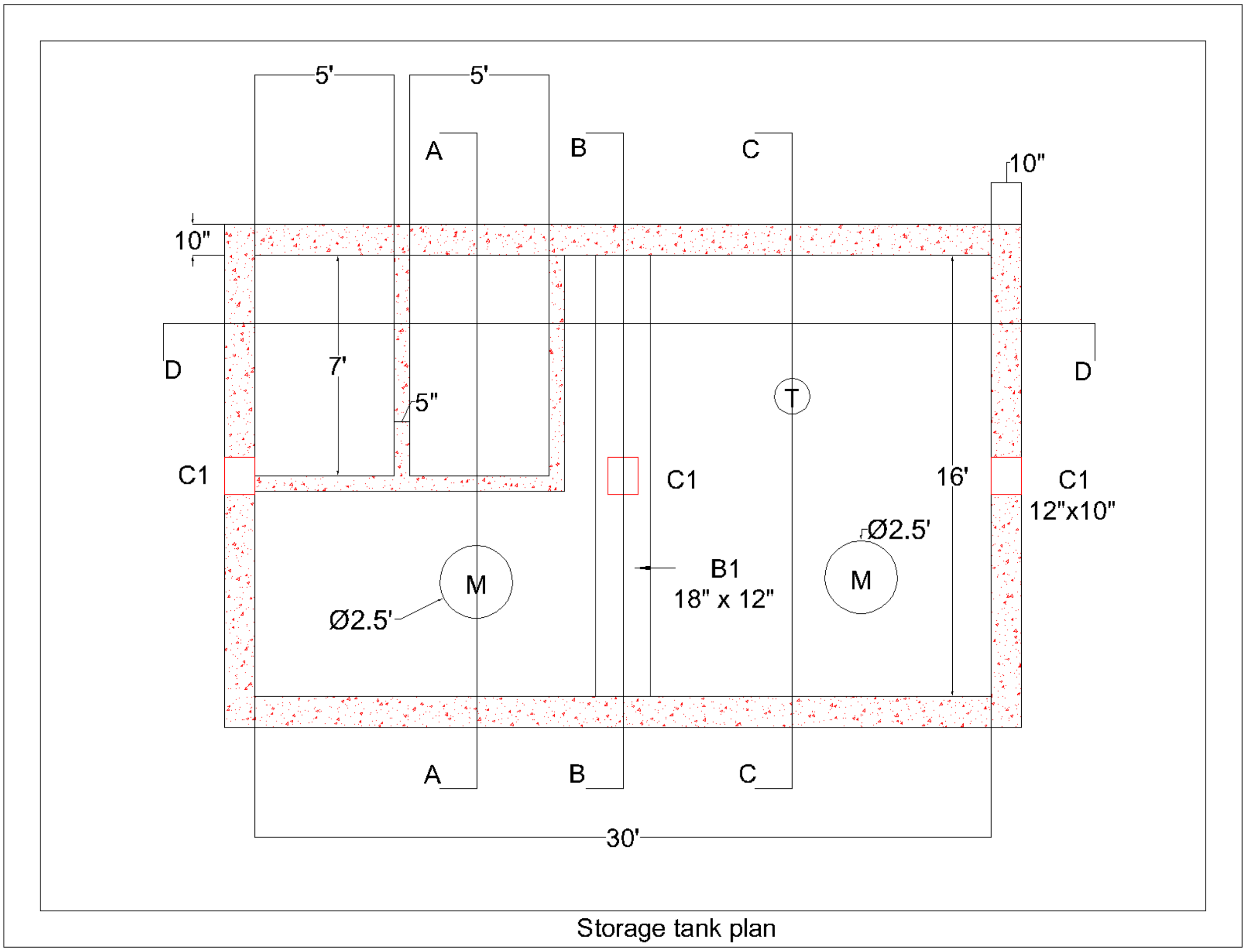


Figure 23: Storage tank plan

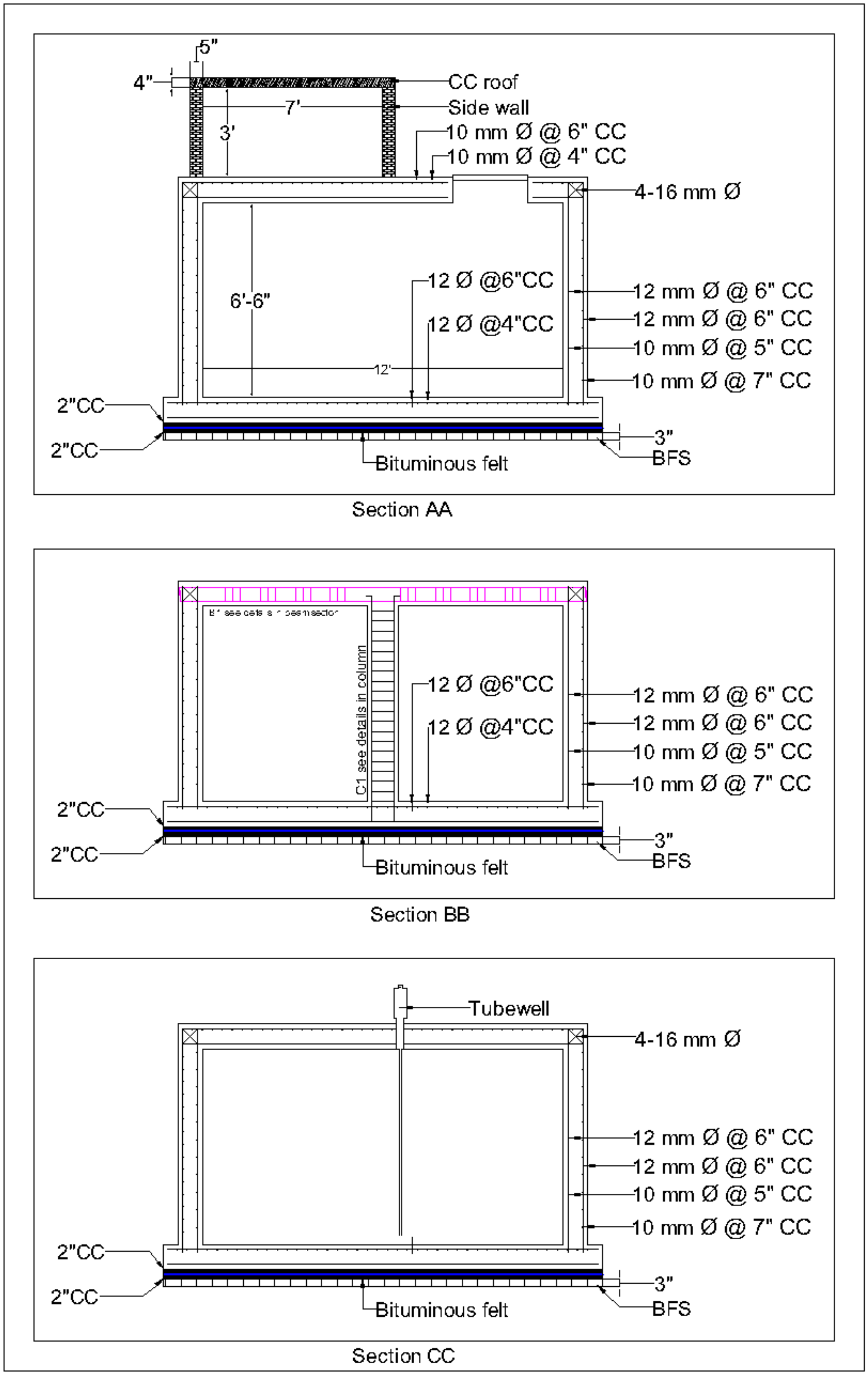


Figure 24: Cross sections of the storage tank

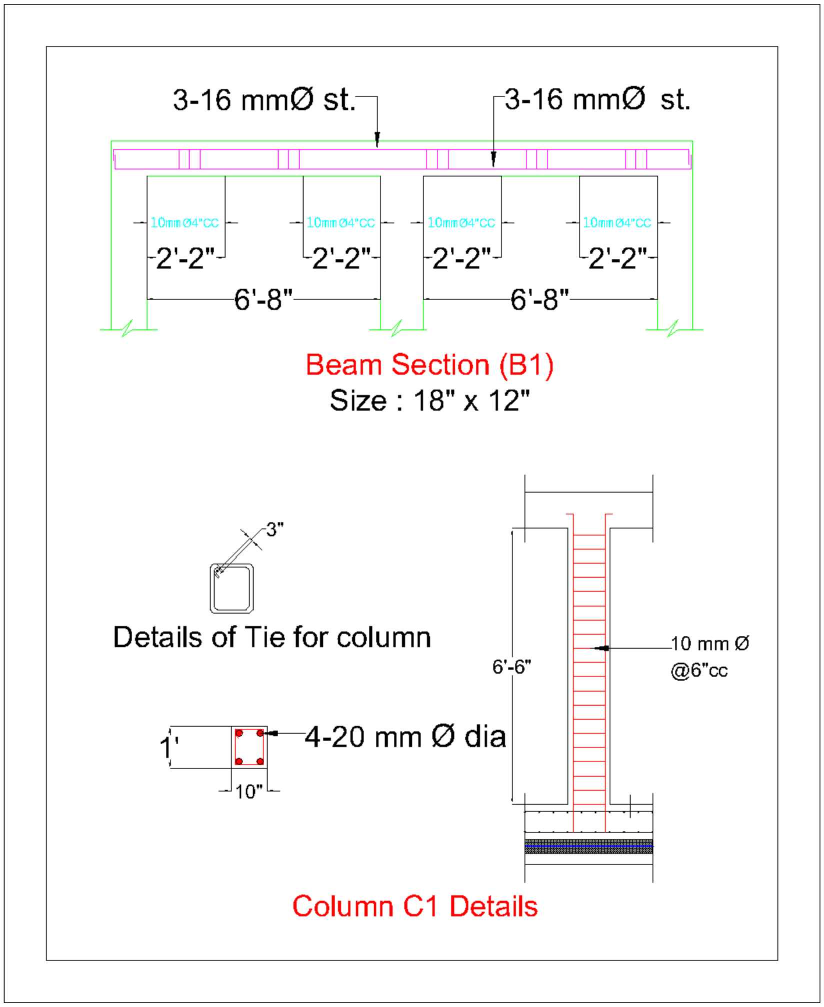


Figure 25: Beam and column sections of the storage tank

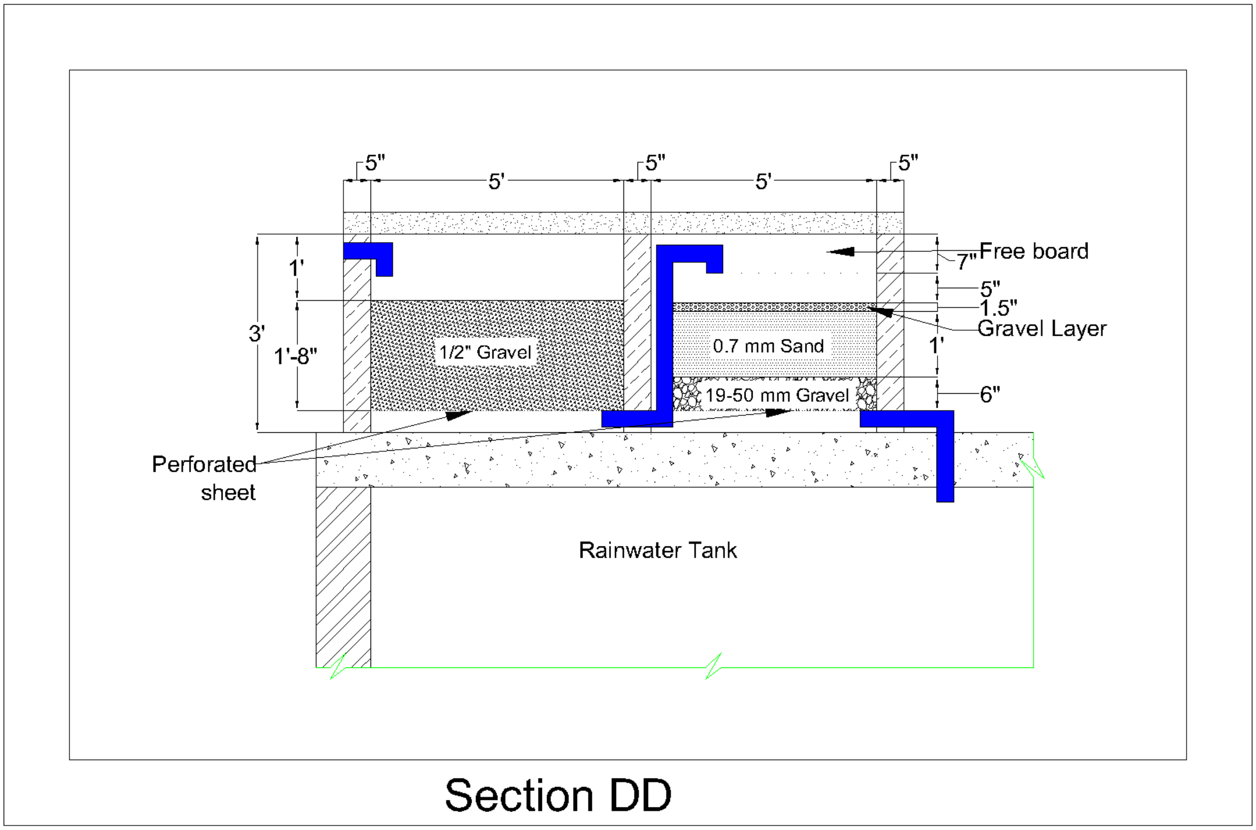


Figure 26: Filter media of the rainwater harvesting system

10.1.4 Community based Pond Water Treatment System (Sky-hydrant)

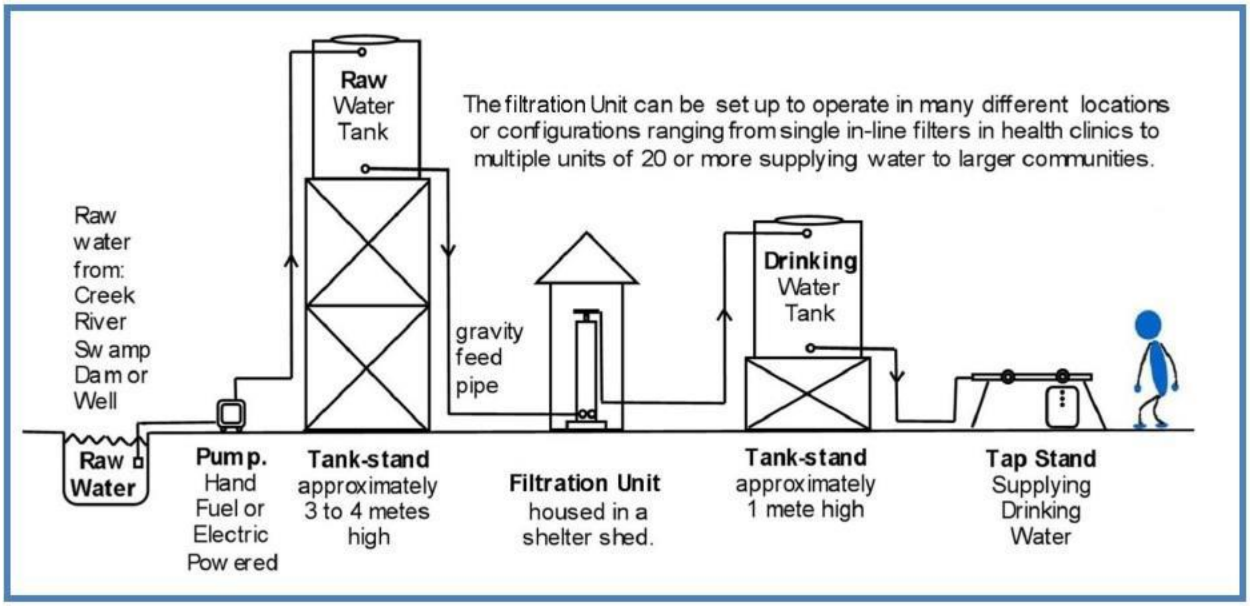


Figure 27: Schematic diagram of Sky-hydrant system

10.2 Bill of Quantity of the Water Technologies

The bill of quantity of the water technologies are provided in the tables below. But it should be noted that the cost might change after customization of the design as per the requirement of the sites, especially for medium and large rainwater harvesting sites.

Table 32: Cost of household rainwater harvesting system

Sl. No.	Components	Total Amount (BDT)
1	Rainwater tank (2,000 L capacity plastic tank @ 11 BDT/L)	22,000
2	Catchment (10' X 6' size CGI sheet)	3,000
3	Gutter, pipe, first flush system, elbow joint, t-bent, thread tape, etc. with installation cost	7,500
4	Filter material, bucket (gravel and sand) and filter stand	3,000
4	Platform material (brick, cement, sand for 4' X 4' X 2' platform with palster) with installation cost	6,500
5	Material transportation cost	5,000
Subtotal		47,000
Grand Total (with 7% contingency)		**50,290**

Table 33: Bill of quantity for medium size rainwater harvesting tanks for 25 households

Sl. No.	Item Description	Unit	Quantity	Unit Rate (BDT)	Total Amount (BDT)
1	Catchment Preparation				
(a)	75 mm Damp proof course (DPC) (1:1.5:3) in cement concrete with cement, Sylhet sand (F.M. 1.2) and stone chips including breaking chips, screening, centering, shuttering, casting, curing and finished with a coat of bitumen including the supply of water, electricity and other charges and costs of masons, tools and plants etc. all complete and accepted by the Engineer.	m^2	75	1,200	90,000
(b)	125 mm brick works with first class bricks in cement sand (F.M. 1.2) mortar (1:4) and making bond with connected walls including necessary scaffolding, raking out joints, cleaning and soaking the bricks for at least 24 hours before use and washing of sand curing at least for 7 days in all floors including cost of water, electricity and other charges etc. all complete and accepted by the Engineer.	m^2	10	890	8,900
2	Earth work (7 m X 5 m X 0.5 m) : Earthwork in excavation of tank of any dimension in all kinds of soil including cutting up to required depth including bailing out water and throwing on the embankment, breaking clods, ramming and leveling, dressing in 225 mm layer with maintaining the side slopes and level of both tank and the embankment as per design and accepted by the Engineer.	m^3	18	500	9,000
3	Brick flat solling with sand filling with labor charge: One layer of brick flat soling in foundation or in floor with first class or picked jhama bricks including preparation of bed and filling the interstices with local sand, leveling etc. complete and accepted by the Engineer.	m^2	35	350	12,250

Sl. No.	Item Description	Unit	Quantity	Unit Rate (BDT)	Total Amount (BDT)
4	Reinforced concrete tank preparation with labor charge: *side wall (6.42 m X 4.42 m X 0.21 m), base (6.5 m X 4.5 m X 0.21 m), roof (6.42 m X 4.42 m X 0.21 m).* Reinforcement cement concrete works using steel shutter with minimum cement content relates to mix ratio 1:1.5:3 having minimum fcr=26mpa,and satisfying a specified compressive strength f'c=21mpa at 28 days on cyliders as per standard practice of code ACI/BNBC/ASTM& Cement conforming to BDS EN-197-1-CEM1,52.5N(52.5MPa)/ASTM-C 150 Type -i,best quality sylhet sand or coarse sand of equivalent F.M 2.2 and 20 mm down well graded stone chip conforming to ASTM C-33 making, shutter, placing shutter in position and maintaining .making shutter water tight properly, placing reinforcement in position, mixing with standard mixer machine with hooper. All complete approved and accepted by the Engineer.	m^3	22	8,000	176,000
5	Reinforce bar (10 mm and 12 mm dia)	Kg	3000	90	270,000
6	Framework, shuttering and necessairy supports: necessary earth work, side filling shuttering.	m^2	200	300	60,000
7	Net finishing : cement plaster (1:4) with neat finishing on inner and outer sides, edges and top, curing etc. with mason charge all complete approved and accepted by the Engineer.	m^2	150	400	60,000
8	Construction and placing of R.C.C. inspection pit cover (slab) in (1:2:4) with 1% reinforcement excluding M.H. cover with locking/unlocking arrangement including necessary earth work, side filling shuttering, curing, cement plaster (1:4) with neat finishing on edges and top, mason charge, etc. all complete approved and accepted by the Engineer.	Nos.	2	12,000	24,000

Sl. No.	Item Description	Unit	Quantity	Unit Rate (BDT)	Total Amount (BDT)
9	µPVC pipe (diameter 4 inch) for downpipe and water conveyance system with installation charge	m	50	600	30,000
10	T-bent, elbow, gate valve, water tap, connection joints and necessariy materials with installation charge	Set	1	40,000	40,000
11	First flush diverter with installation charge	Set	1	10,000	10,000
12	Filter materials (gravel, coarse sand)	m^3	2	5,000	10,000
13	Tube well for water collection with pipes and other fixtures with installation charge	Set	1	11,500	11,500
14	Transportation of materials	L.S.	1	100,000	100,000
15	Visibility materials (sign boards, writings)	L.S.	1	30,000	30,000
16	**Total Cost**				941,650
17	**7% Contingency**				65,916
18	**Grand Total**				1,007,566

Table 34: Bill of quantity for large size rainwater harvesting tanks for 50 households

Sl. No.	Item Description	Unit	Quantity	Unit Rate (BDT)	Total Amount (BDT)
1	**Catchment Preparation**				
(a)	75 mm Damp proof course (DPC) (1:1.5:3) in cement concrete with cement, sylhet sand (F.M. 1.2) and stone chips including breaking chips, screening, centering, shuttering, casting, curing and finished with a coat of bitumen including the supply of water, electricity and other charges and costs of masons, tools and plants etc. all complete and accepted by the Engineer.	m^2	150	1,200	180,000
(b)	125 mm brick works with first class bricks in cement sand (F.M. 1.2) mortar (1:4) and making bond with connected walls including necessary scaffolding, raking out joints, cleaning and soaking the bricks for at least 24 hours before use and washing of sand curing at least for 7 days in all floors including cost of water, electricity and other charges etc. all complete and accepted by the Engineer.	m^2	15	890	13,350
2	Earth work (7 m X 5 m X 0.5 m) : Earthwork in excavation of tank of any dimension in all kinds of soil including cutting up to required depth including bailing out water and throwing on the embankment, breaking clods, ramming and leveling, dressing in 225 mm layer with maintaining the side slopes and level of both tank and the embankment as per design and accepted by the Engineer.	m^3	50	500	25,000
3	Brick flat solling with sand filling with labor charge: One layer of brick flat soling in foundation or in floor with first class or picked jhama bricks including preparation of bed and filling the interstices with local sand, leveling etc. complete and accepted by the Engineer.	m^2	50	350	17,500

Sl. No.	Item Description	Unit	Quantity	Unit Rate (BDT)	Total Amount (BDT)
4	Reinforced concrete tank preparation with labor charge: *side wall (6.42 m X 4.42 m X 0.21 m), base (6.5 m X 4.5 m X 0.21 m), roof (6.42 m X 4.42 m X 0.21 m).* Reinforcement cement concrete works using steel shutter with minimum cement content relates to mix ratio 1:1.5:3 having minimum fcr=26mpa,and satisfying a specified compressive strength f'c=21mpa at 28 days on cyliders as per standard practice of code ACI/BNBC/ASTM& Cement conforming to BDS EN-197-1-CEM1,52.5N(52.5MPa)/ASTM-C 150 Type -i,best quality sylhet sand or coarse sand of equivalent F.M 2.2 and 20 mm down well graded stone chip conforming to ASTM C-33 making, shutter, placing shutter in position and maintaining .making shutter water tight properly, placing reinforcement in position, mixing with standard mixer machine with hooper. All complete approved and accepted by the Engineer.	m^3	30	9,800	294,000
5	Reinforce bar (10 mm and 12 mm dia)	Kg	4500	90	405,000
6	Framework, shuttering and necessairy supports: necessary earth work, side filling shuttering.	m^2	400	300	120,000
7	Net finishing : cement plaster (1:4) with neat finishing on inner and outer sides, edges and top, curing etc. with mason charge all complete approved and accepted by the Engineer.	m^2	250	400	100,000
8	Construction and placing of R.C.C. inspection pit cover (slab) in (1:2:4) with 1% reinforcement excluding M.H. cover with locking/unlocking arrangement including necessary earth work, side filling shuttering, curing, cement plaster (1:4) with neat finishing on edges and top, mason charge, etc. all complete approved and accepted by the Engineer.	Nos.	2	12,000	24,000
9	µPVC pipe (diameter 4 inch) for downpipe and water conveyance system with installation charge	m	50	600	30,000

Sl. No.	Item Description	Unit	Quantity	Unit Rate (BDT)	Total Amount (BDT)
10	T-bent, elbow, gate valve, water tap, connection joints and necessariy materials with installation charge	Set	1	40,000	40,000
11	First flush diverter with installation charge	Set	1	10,000	10,000
12	Filter materials (gravel, coarse sand)	m^3	2	8,575	17,150
13	Tube well for water collection with pipes and other fixtures with installation charge	Set	1	12,000	12,000
14	Transportation of materials	L.S.	1	200,000	200,000
15	Visibility materials (sign boards, writings)	L.S.	1	30,000	30,000
16	**Total Cost**				1,518,000
17	**7% Contingency**				106,260.0
18	**Grand Total**				1,624,260

Table 35: Bill of quantity for large size rainwater harvesting tanks for 50 households with new roof (catchment)

Sl. No.	Item Description	Unit	Quantity	Unit Rate (BDT)	Total Amount (BDT)
1	**Catchment Preparation**				
(a)	150 sq. m. iron sheet (best quality) with its installation cost	m^2	150	600	90,000
(b)	Reinforced concrete tank preparation with labor charge: *side wall (6.42 m X 4.42 m X 0.21 m), base (6.5 m X 4.5 m X 0.21 m), roof (6.42 m X 4.42 m X 0.21 m).* Reinforcement cement concrete works using steel shutter with minimum cement content relates to mix ratio 1:1.5:3 having minimum fcr=26mpa,and satisfying a specified compressive strength f'c=21mpa at 28 days on cyliders as per standard practice of code ACI/BNBC/ASTM& Cement conforming to BDS EN-197-1-CEM1,52.5N(52.5MPa)/ASTM-C 150 Type -i,best quality sylhet sand or coarse sand of equivalent F.M 2.2 and 20 mm down well graded stone chip conforming to ASTM C-33 making, shutter, placing shutter in position and maintaining .making shutter water tight properly, placing reinforcement in position, mixing with standard mixer machine with hooper. All complete approved and accepted by the Engineer.	Nos.	8	12,000	96,000
(c)	Wooden structure for support of catchment with the cost of cutting, shaping of wooden frames, and installation. All complete, approved and accepted by the enigneer.	m^2	150	449	67,350
2	Reinforce bar (10 mm and 12 mm dia)	m^3	50	500	25,000
3	Framework, shuttering and necessairy supports: necessary earth work, side filling shuttering.	m^2	50	350	17,500
4	Net finishing : cement plaster (1:4) with neat finishing on inner and outer sides, edges and top, curing etc. with mason charge all complete approved and accepted by the Engineer.	m^3	30	9,800	294,000

Sl. No.	Item Description	Unit	Quantity	Unit Rate (BDT)	Total Amount (BDT)
5	Construction and placing of R.C.C. inspection pit cover (slab) in (1:2:4) with 1% reinforcement excluding M.H. cover with locking/unlocking arrangement including necessary earth work, side filling shuttering, curing, cement plaster (1:4) with neat finishing on edges and top, mason charge, etc. all complete approved and accepted by the Engineer.	Kg	4500	90	405,000
6	Framework, shuttering and necessairy supports: necessary earth work, side filling shuttering.	m²	400	300	120,000
7	Net finishing : cement plaster (1:4) with neat finishing on inner and outer sides, edges and top, curing etc. with mason charge all complete approved and accepted by the Engineer.	m²	250	400	100,000
8	Construction and placing of R.C.C. inspection pit cover (slab) in (1:2:4) with 1% reinforcement excluding M.H. cover with locking/unlocking arrangement including necessary earth work, side filling shuttering, curing, cement plaster (1:4) with neat finishing on edges and top, mason charge, etc. all complete approved and accepted by the Engineer.	Nos.	2	12,000	24,000
9	µPVC pipe (diameter 4 inch) for downpipe and water conveyance system with installation charge	m	50	600	30,000
10	T-bent, elbow, gate valve, water tap, connection joints and necessariy materials with installation charge	Set	1	40,000	40,000
11	First flush diverter with installation charge	Set	1	10,000	10,000
12	Filter materials (gravel, coarse sand)	m³	2	8,575	17,150
13	Tube well for water collection with pipes and other fixtures with installation charge	Set	1	12,000	12,000
14	Transportation of materials	L.S.	1	200,000	200,000
15	Visibility materials (sign boards, writings)	L.S.	1	30,000	30,000
16	**Total Cost**				1,618,000
17	**7% Contingency**				113,260
18	**Grand Total**				1,731,260

Table 36: Cost of Sky-hydrant with climate resilient components

Sl. No.	Components	Total Amount (BDT)
1	Sky-hydrant unit with transportation and installation costs	450,000
2	Disaster resilient housing and accessories (Solar Panel, battery, pumps, pipes, raw water and fresh water reservoirs, etc.) with transportation and installation costs	600,000
3	Embankment construction above flood level including labor and transportation costs	100,000
Subtotal		1,150,000
Total (with 7% contingency)		**1,230,500**

10.3 Operation and Maintenance Cost of Water Technologies

The tentative operation and maintenance cost of the water technologies are provided in this section.

Table 37: O&M cost per year for household rainwater harvesting systems

Sl. No.	Item Description	Cost per Year (BDT)
1	Yearly maintenance (repairing of gutter, pipe, joints, taps, etc.)	600
Total (per year)		**600**

Table 38: O&M cost per year for community/household based medium size rainwater harvesting systems

Sl. No.	Item Description	Cost per Year (BDT)
1	Caretaker salary (BDT 10,000 per month)	120,000
2	Yearly maintenance (repairing of taps, joints, gutters, pipes, etc.)	12,000
Total (per year)		**132,000.00**

Table 39: O&M cost per year for community/household based large size rainwater harvesting systems

Sl. No.	Item Description	Cost per Year (BDT)
1	Caretaker salary (BDT 10,000 per month)	120,000
2	Yearly maintenance (repairing of taps, joints, gutters, pipes, etc.)	18,000
Total (per year)		**138,000.00**

Table 40: O&M cost per year for community based Sky-hydrant systems

Sl. No.	Item Description	Cost per Year (BDT)
1	Battery Maintenance	12,000
2	Module maintenance cost (travel and remuneration fees for technical experts from suppliers and change of membrane and filter materials)	100,000
3	Yearly maintenance of accessories	30,000
4	Caretaker salary (BDT 12,000/month)	144,000
5	Embankment maintenance	30,000
Total (per year)		**316,000**

11. Financial Needs

This section includes the overall budget. Similar to the Union reports, this section has been kept blank as the total cost might change.

12. Conclusion

There is a huge demand of potable water in the climate vulnerable coastal 39 unions of 5 Upazilas under district Khulna and Satkhira. The existing water technologies quantitatively covers only 19.02% of the population for safe water supply and a huge supply gap (80.98%) remains to be met by the external support and intervention under Green Climate Fund (GCF) project. The gaps need to be filled up by identification of climate resilient appropriate water technologies, which can adequately sustainably provide safe drinking water services to all uncovered people of the above selected areas and reduce significantly the hardship of the people particularly the women for collection of water and increase their amenities for improved living and health.

A rapid but comprehensive study was conducted in the above areas, analyzed the situation by adopting the participatory and consultative approach and proposed climate-resilient technology solutions to provide a sustainable water supply for the communities. Under this study the climate situation and its impact on the drinking water sources and facilities was analyzed, appropriate technologies were selected and required capital operational cost investment was estimated.

Analysing varying hydro-geological and climatic conditions of the study area and in consideration of different technical, social, economic and environmental factors, 2 appropriate and sustainable technological options were proposed for increased and improved coverage of safe water. These are, Rain Water Harvesting (RWH) unit for ensuring safe storage of rain water and Sky-hydrant, an improved filter module for treatment of pond water in the areas where adequate fresh ponds are available. The total quantity of these options was estimated based on existing demand and standard design capacity of the options and accordingly total investment cost was estimated. It was found that a total of BDT XXXXXXXX is required in terms of investment and recurring cost to make safe water service provision for uncovered population size projected over next 20 years. The study also recommended implementation model and institutional arrangement and clear exit strategy for developing capacity of the community and private sector and empowering women for sustainable operation and maintenance of the proposed improved water facilities in the study areas.

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